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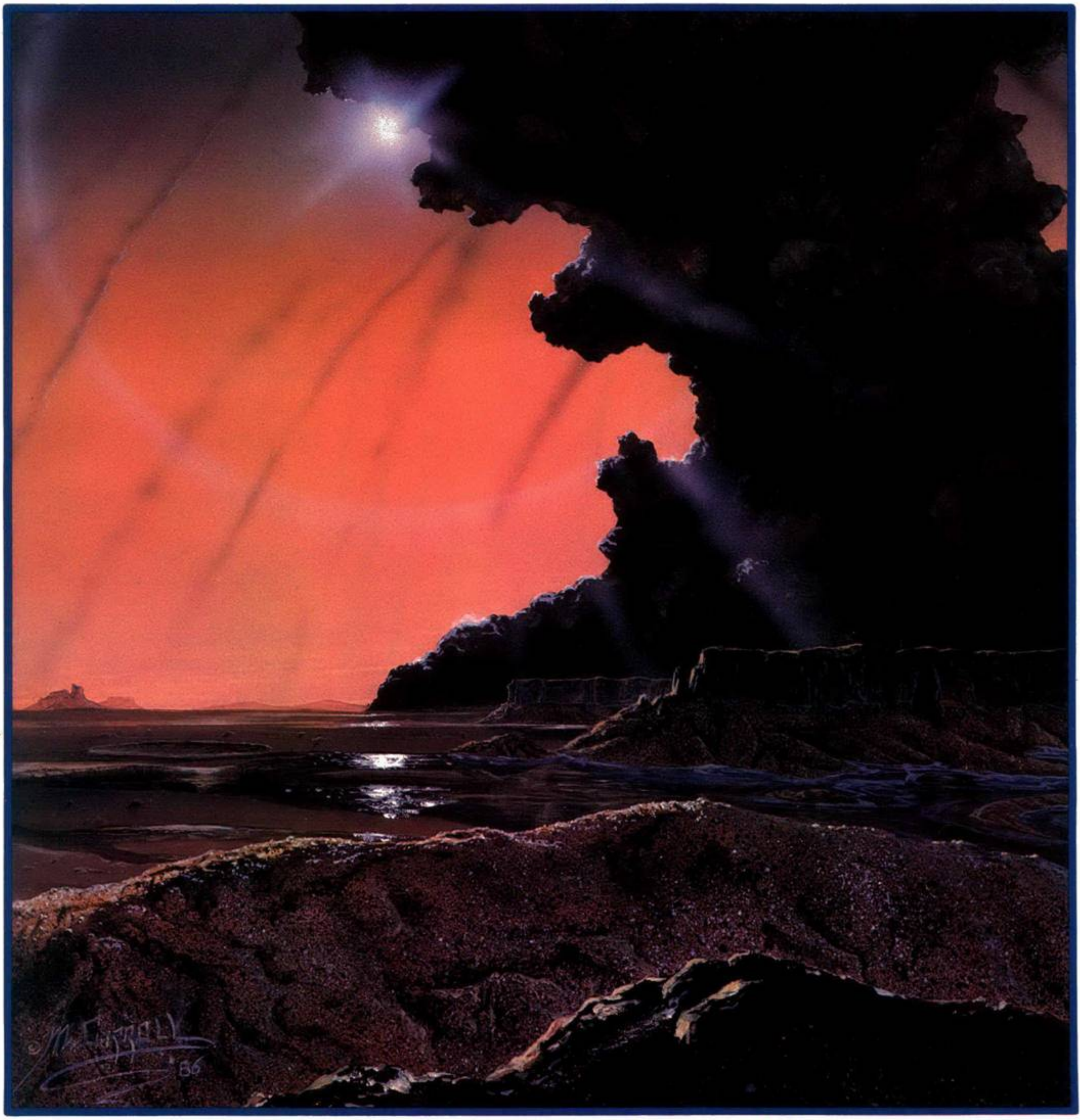

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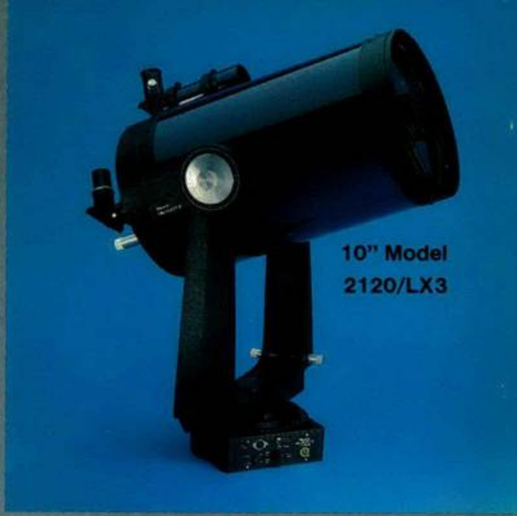

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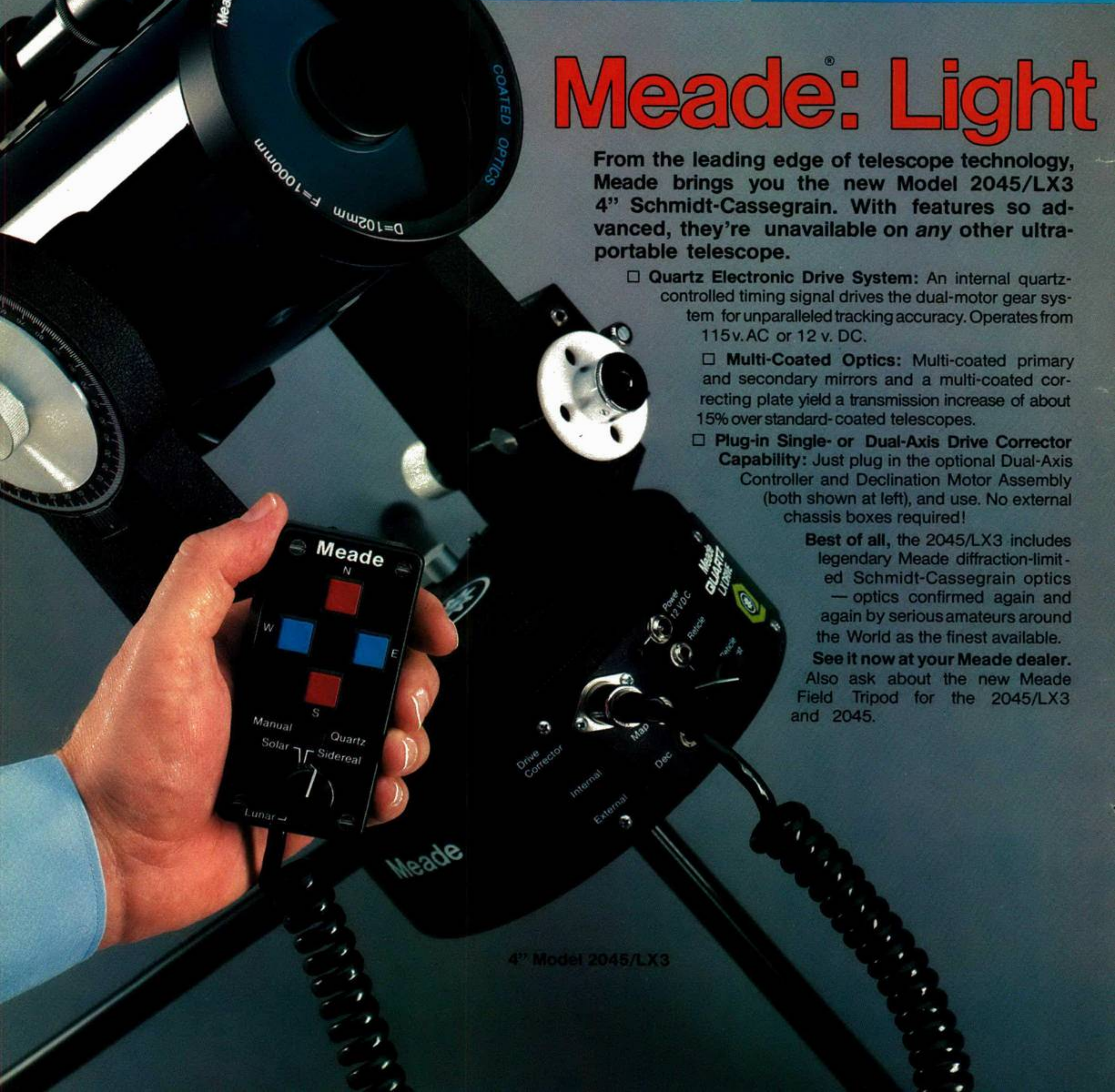
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Cover: A cloud of dust and steam towers into the clear Martian sky moments after the impact of an asteroid. The shock waves and heat resulting from the impact melt frozen subsurface lakes, which causes flash floods. Painting by Michael Carroll. These pages: Moonlike in some respects, Earthlike in others, the valleys and plains in the western reaches of Mangala Valles on Mars were shaped predominantly by wind erosion. Photo courtesy of Al McEwen, United States Geological Survey.

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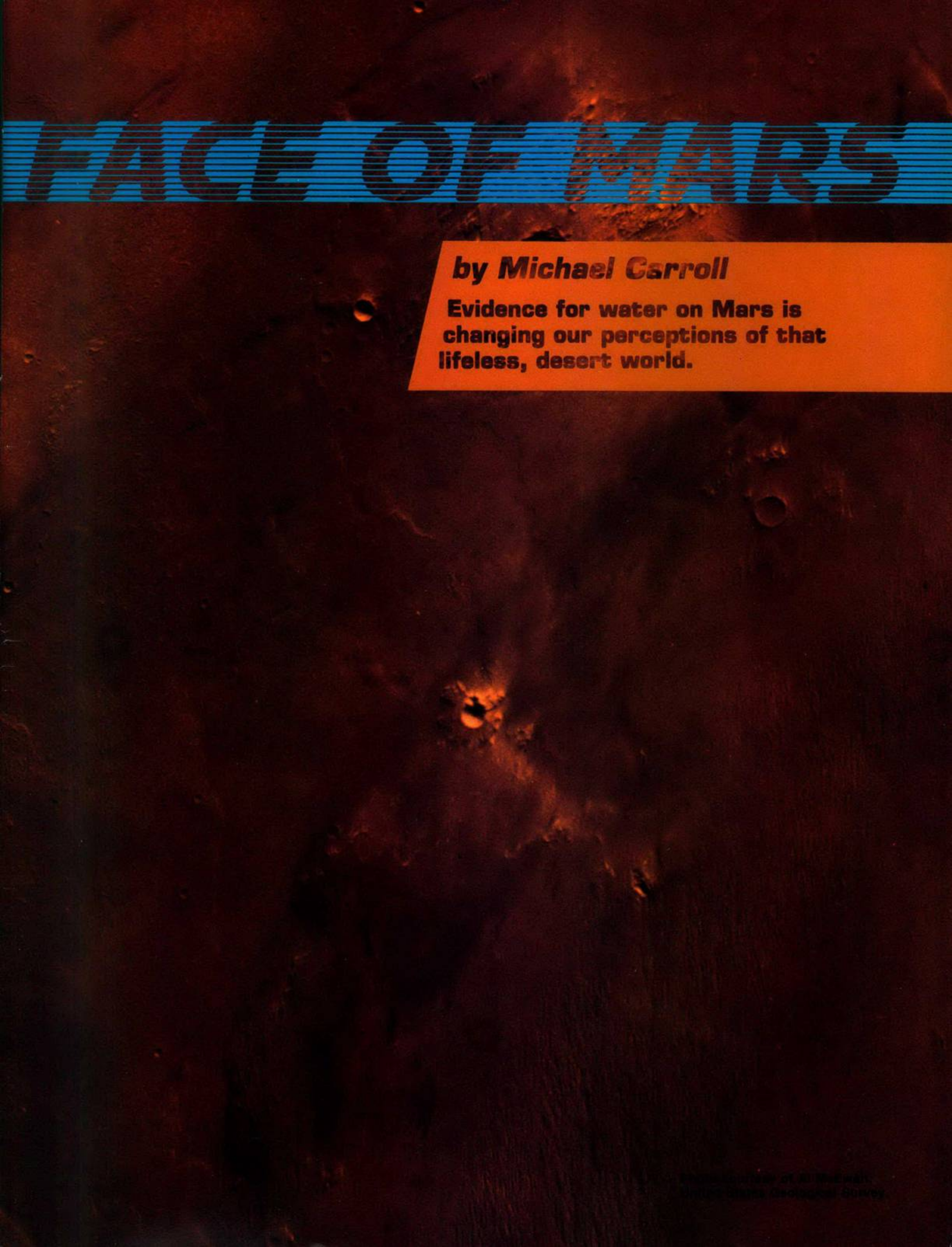
THE CHANGING

FACE OF MARS



by Michael Carroll

Evidence for water on Mars is changing our perceptions of that lifeless, desert world.

[illegible]
United States Geological Survey

Ten thousand times a hundred thousand dusty years ago,
Where now extends the Plain of Gold did once my river flow.
It stroked the stones and spoke in tongues and splashed against my face
Till ages rolled — the Sun shone cold on this unholy place.

So many stars bedeck my skies, when once there were but few,
But oh, to know again the clouds that hid them from my view.
My ochred cliffs and rusted sands stand regal and serene,
But oh, my wan and wasted world, I miss your blue and green.

But it's just the weight of waiting, not a deathwatch o'er a friend.
Tomorrow has a starting as does yesterday an end.
For the water of my river and the air that was my wind,
Though bound in rocks and wintry wastes, I pray may flow again.

My ochred cliffs and rusted sands stand regal and serene,
But oh, my wan and wasted world, I miss your blue and green.

© 1980 Jonathan Eberhart, "Lament for a Red Planet"
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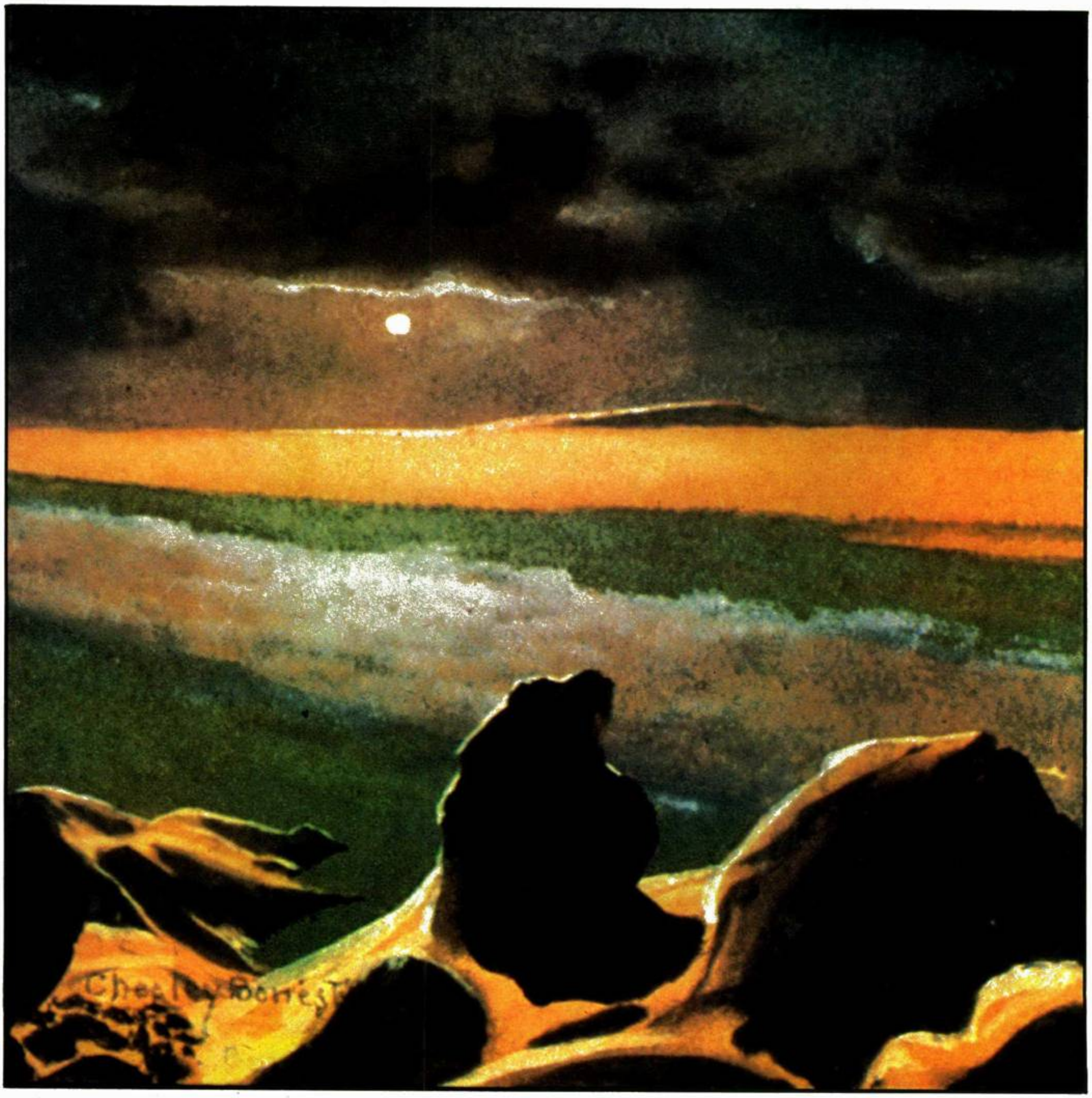


The view of Mars sent back by Mariner 4 as it coasted by the planet on July 15, 1965, showed an ancient, arid, quiet world. It was the Mars of 3.5 billion years ago: a cold, Moonlike place extensively cratered by the bombardments of planetesimals in the early part of the solar system. Mariners 6 and 7 returned similar images of this blemished terrain — extending from the equator to the southern polar cap — during their flybys in 1969. But a different Mars was to give up its secrets to later probes.

Mariner 9 was the first spacecraft to photograph the surface of Mars from orbit in 1971. It was followed by the short-lived Soviet Mars 5 probe in 1973 and in 1976 by twin Viking orbiters and landers. Through the cameras of these probes scientists beheld a landscape sculpted by wind, tormented by giant volcanoes, crossed by great rift valleys, and battered by meteors and comets.

The evidence sent back by the probes was irrefutable: Mars is a hostile, barren world. Summer temperatures seldom rise above the melting point of ice. The atmosphere of Mars is as thin as that of Earth at 100,000 feet and is made up almost entirely of carbon dioxide. And though the planet's weather has its quiescent moments, with graceful clouds of water ice hugging the flanks of the great volcanoes or nestling among the canyons in the early mornings, it can also turn violent, sending planet-wide dust storms shrieking through the Martian sky for weeks and months at a time.

But the orbiters and landers also turned up intriguing new evidence suggesting that the dry, desert planet may have once been crisscrossed with lakes and rivers of water and that catastrophic flooding may have occurred on an immense scale. In fact, some scientists believe a shallow sea might have once covered part of Mars' northern hemisphere.

The Masks of Mars

Our conception of Mars seems to have come full circle. In the 1800s and through most of the 1900s a great deal of discussion focused on the existence of "canals," supposedly built by Martians to divert water from the poles to irrigate their deserts. But the debate back then was really about water, because water means the possibility of life "as we know it," and water flowing in straight channels implies something about that life — namely, intelligence.

The term "canali" was coined by the Italian astronomer Pietro Angelo Secchi in the 1860s to describe faint lines that appear to spread in a complicated pattern across the Martian disk. Another Italian observer, Giovanni Schiaparelli, also used the term after observing similar linear features during the Martian opposition of 1877, when Mars was only 56 million kilometers from Earth. Two years later Schiaparelli, who had made many maps of Mars, reported that many of the single lines appeared to have become double parallel lines.

Other observers, most notably the Americans William Pickering and Percival Lowell, followed Schiaparelli and documented a network of linear markings on a myriad of maps. Gradually, the case for the existence of canals as planet-wide waterways gained momentum. Circumstantial evidence certainly supported the canal theory. Each Martian spring, as the polar caps melted, these apparent canals would swell and darken, which implied the growth of adjacent vegetation. But the canals and their relationship to water and Martian life — intelligent or otherwise — kindled much controversy. Among those who doubted the existence of the canals were capable observers such as Asaph Hall of the U.S. Naval Observatory, discoverer of Mars' two tiny moons, and E. M. Antoniadi, director of France's Meudon Observatory. In 1913 Antoniadi wrote in the magazine *Popular Astronomy* that "the astronomer of the future will sneer at these wonders; and canal fallacy, after retarding progress for a third of a century, is doomed to be relegated into the myths of the past."

The controversy has persisted into modern times. The wet-Martian climate model bustling with life was still popular as late as the 1950s, as evidenced by the now-classic book *The Exploration of Mars* by Willi Ley, Werner Von Braun, and Chesley Bonestell. In the introductory chapter the authors confidently state: "This is the picture of Mars at mid-century: a small planet of which three-quarters is cold desert, with the rest covered with a sort of plant life. . . ." And, in 1962, Vesto Melvin Slipher of Lowell Observatory published a group of photographs he claimed showed "so many canals and oases in the same position, form, and character as drawn on the Lowell and Lick Observatory maps of the planet, that . . . their existence as true markings on the planet has been clearly established."

As Earth-based measurements of Mars were refined in the 1960s, evidence emerged that Mars was very cold, very dry, and severely lacking in atmosphere. Almost overnight our conception of Mars changed from that of an ocher land of desert oases fed by a global web of waterways to that of a dry world of lichens clinging to life through bitter winters. Many scientists gave up on Martian life. But even the most conservative researchers were stunned by the barren landscape transmitted to Earth from our first planetary trailblazer to Mars, Mariner 4.

"I was surprised," says Michael Carr, a member of the Mariner imaging team at the United States Geological Survey and later the leader of the Viking Lander imaging team. "Although none of us really expected to find canals, we did expect to see linear features. . . . And after Mariners 6 and 7 we thought Mars to be very Moonlike. The atmosphere was very thin. The air was very dry. There seemed to be no spectral evidence of water."

Ironically, the Mariner 4, 6, and 7 flybys covered only the southern hemisphere of Mars, which is geologically older than the northern hemisphere (for reasons that remain unknown). Crater densities in the southern regions are similar to those in the lunar highlands. As we learned in 1971, Mars' northern hemisphere is where the exciting (and controversial) geological activity occurred. The craters in many areas of the northern hemisphere have been obliterated or altered by volcanic activity, the formation of canyons, wind erosion, and what appears to be catastrophic flooding. These great flood plains and water-sculpted valleys were completely missed by the first three Mariners. It's no wonder scientists, faced with photographic evidence of an ancient, cratered wasteland, concluded Mars was and always had been an ancient, cratered wasteland of a world. In a NASA report, "Two over Mars," published just after the Mariner 6 and 7 flybys, geologist James Wilson stated: "The survival of so many craters of great age makes it clear, if these features are as old as they look, that dense atmosphere and broad seas,

The Mars of the 1950s was a desert world crisscrossed by a network of straight canals supporting vegetation, as depicted in this classic painting by Chesley Bonestell. Space Art International.

with the rapid and drastic erosion they produce, never existed on Mars."

Although such overt evidence seemingly laid to rest any hope that significant amounts of water once existed on Mars, water kept surfacing as an integral factor in models and theories. In the 1970s, for example, planetary scientist John Lewis and others continued developing models of planetary evolution. These models indicated there would be more volatiles — including water — on planets farther from the Sun than on those closer to it. Applied to Mars, Lewis' projections implied Mars should have formed with much more water than the Mariner spacecraft measurements suggested.

The exploration of Mars entered a new phase with the Mariner 9 orbiter. On November 14, 1971, the rocket engine aboard this probe fired for over a quarter of an hour, placing the spacecraft into an elliptical orbit around Mars. Although the cameras functioned perfectly, scientists had to wait until the end of the year to see the surface because it was obscured by a planet-wide dust storm. As the storm subsided, investigators began to glimpse strange new features. The earliest photos showed several dark spots looming out of the dust clouds day by day. As the dust cleared, these spots were identified as volcanoes. *Big* volcanoes. The largest, Olympus Mons, is twice as high as Mount Everest and has a base diameter equal to the distance from San Diego to San Francisco. It is the single largest volcano in the solar system.

More surprises were to come. The photographs revealed what appeared to be dry riverbeds winding across the dry, cratered landscape. Moreover, there was evidence of flooding on an immense scale. Mars was not as dead as it seemed.

The most recent reconnaissance of Mars was by the Viking project. Launched in 1975, two orbiters studied the planet for over two years from space, while two landers took samples directly on the surface of Mars. One orbiter lasted nearly five years, and Viking Lander 1, designed to endure the hostile Martian environment for ninety days, lasted over five years. So much data was returned that it is still being analyzed.

Searching for Hidden Water

Based on data returned by the Mariner 9 and Viking spacecraft, how does the face of Mars look today?

"Since the day the first Viking landed, we have become aware that there is even more water, and we understand it better," says astronomer William K. Hartmann. Hartmann, now at the Planetary Science Institute, was on the Mariner 9 imaging team. "Viking found salts on the surface, which suggest water that evaporated."

Whatever water exists on Mars today is hidden well. Liquid water cannot exist on the surface because of the planet's low atmospheric pressure, which is provided by dry CO_2 gas instead of water vapor. Water must either be frozen solid or exist as vapor. The water vapor in the parched Martian air is less than 0.03 percent of the total, which makes Mars drier than the driest of Earth's deserts. Even ground ice cannot exist within 30 degrees north or south of the equator because of the temperatures and pressures found there.

Mars appears to have been in this arid state for most of its existence. Even so, we see such erosion features as terrain "slumping" (the migration of surface material), which may be due to subsurface ice. We see what appear to be branchlike channels and tributaries remarkably similar to those on Earth. And on the plains we see tear-shaped "islands" that might have been shaped by flowing water. Some researchers believe a denser atmosphere and higher water content must have existed at some time in the past to account for the extensive water erosion evident today on the face of the Red Planet.

But when? Did all of this happen during the formation of Mars, before most of its atmosphere was lost to space or locked within the rocks? Or did it happen more recently? One possible answer lies in the analysis of the climatic changes that have occurred on Mars.

As a comparison, the Earth has gone through several major climatic changes. Some 18,000 years ago glaciers covered North America as far south as Chicago and spread over Europe as far south as London. This ice age seems to be linked to other ice ages within the past 100,000 years. In his book *Moons and Planets*, Hartmann says, "The ice ages are probably controlled mostly by periodic changes in precession (21,000-year dominant periodicity) and obliquity (41,000-year dominant periodicity). These astronomical effects change the amount and duration of sunlight striking the polar caps each year and thus affect the polar ice thickness, the ocean level, and world climate."

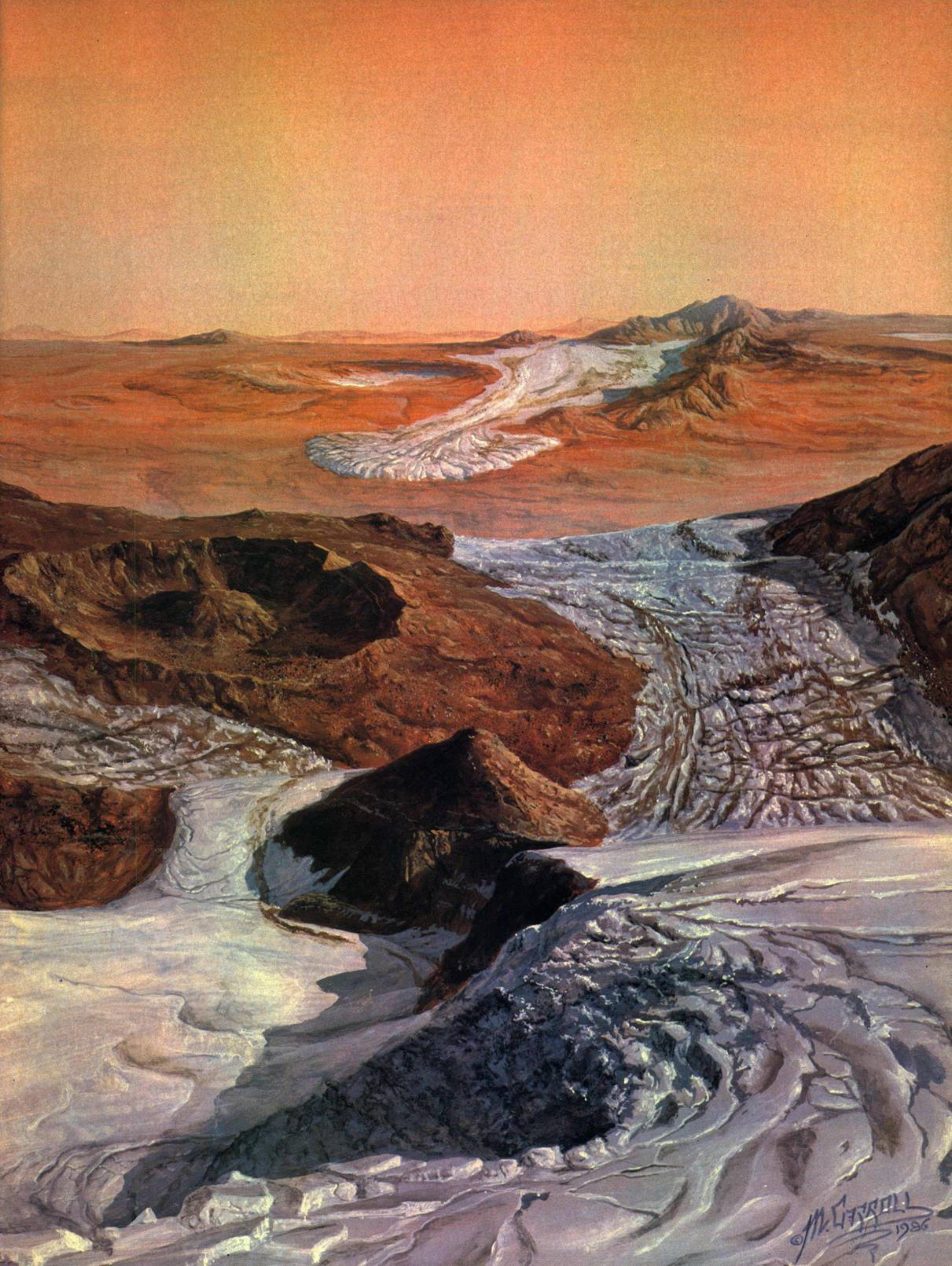
Mars, too, may undergo similar climatic changes. During cycles lasting 120,000 and 1.2 million years, Mars' obliquity (the angle between the planet's spin axis and the pole of its orbital plane) ranges from 17 degrees to 34 degrees. This tips the planet's poles more and then less toward the Sun, which causes a variation greater than 60 percent in solar energy falling on the poles.

The eccentricity (the extent to which an orbit is noncircular) of Mars' orbit also varies in a cycle 178,000 years long, causing a variation in solar flux of about 23 percent at the poles. These changes in solar energy may have produced major transformations in the atmosphere by releasing large amounts of water and carbon dioxide from the melting poles. This process could have raised the atmospheric pressure on Mars from the present 6 millibars to as much as 45 millibars. (As a comparison, the air pressure at sea level on Earth is 1,000 millibars.)

Thus, some researchers suggest the climate on Mars 50,000 years ago was much warmer because the relatively dense, moist atmosphere trapped heat via the "greenhouse effect." As geologist Dave Pieri of the Jet Propulsion Laboratory in Pasadena, California, points out, "Mars began with a much more reduced atmosphere (containing more ammonia and methane). Even a modest greenhouse effect with a slight reducing atmosphere will give higher temperatures." At present, according to some theorists, Mars is in a great ice age that will end some 50,000 years from now when the northern latitudes are heated again.

Although it is appealing, this "wet-climate" theory doesn't fit with the time scale derived by counting craters, the number and distribution of which can be used as a benchmark for dating a particular region of a planet. Typically, geologically old areas have the most and best-preserved craters. Studies of cratered surfaces on Mars point to ages measured in billions — not thousands — of years. Indeed, the planet's ancient terrain is too well preserved to account for scattered rain showers within the

Some planetary geologists believe massive glaciers moved across the plains of Mars carving canyons and valleys. In this artist's conception the Martian glacier in the background ends in a wide fan of ice, while the glacier in the foreground flows around a crater. Painting by Michael Carroll.


M. Carroll
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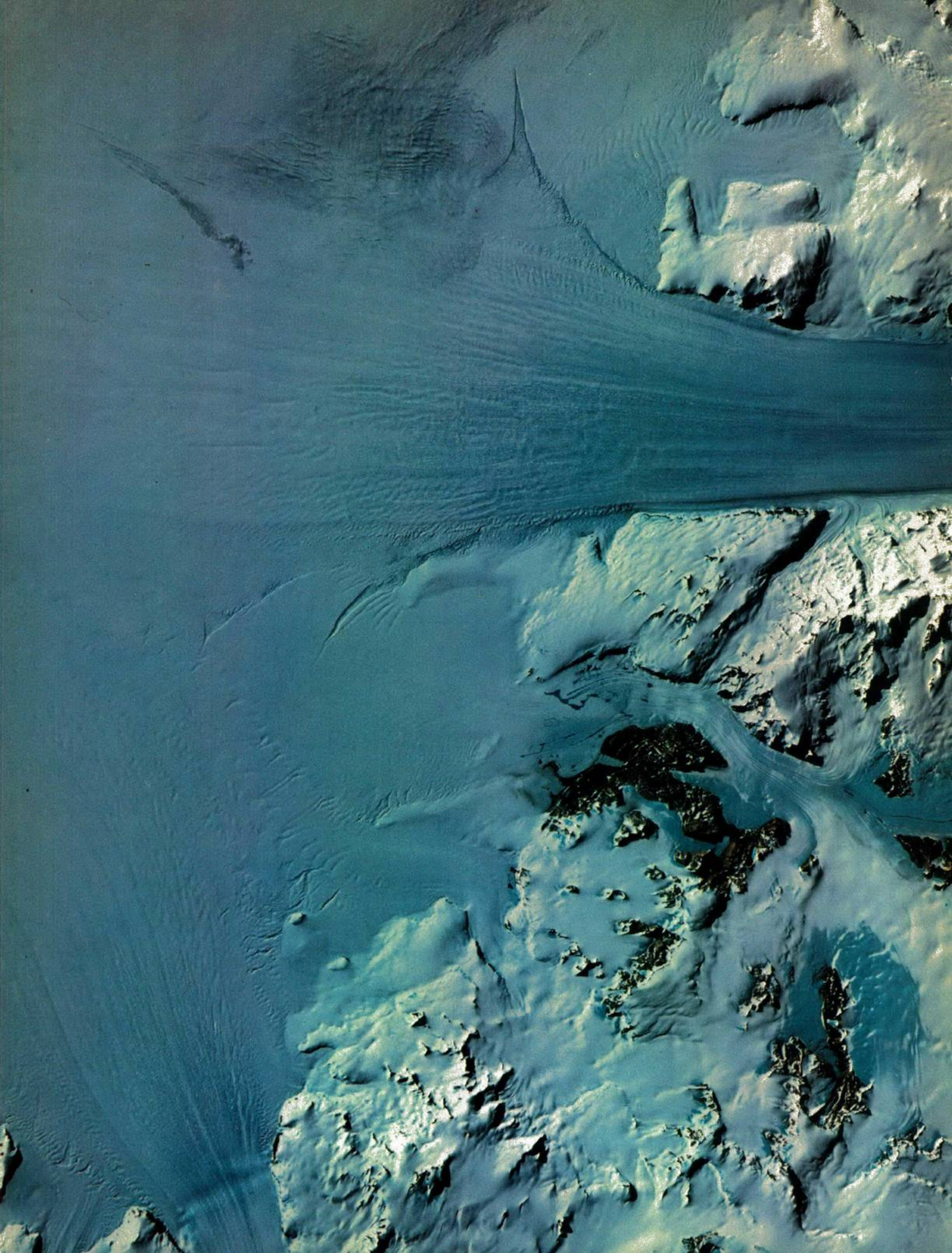
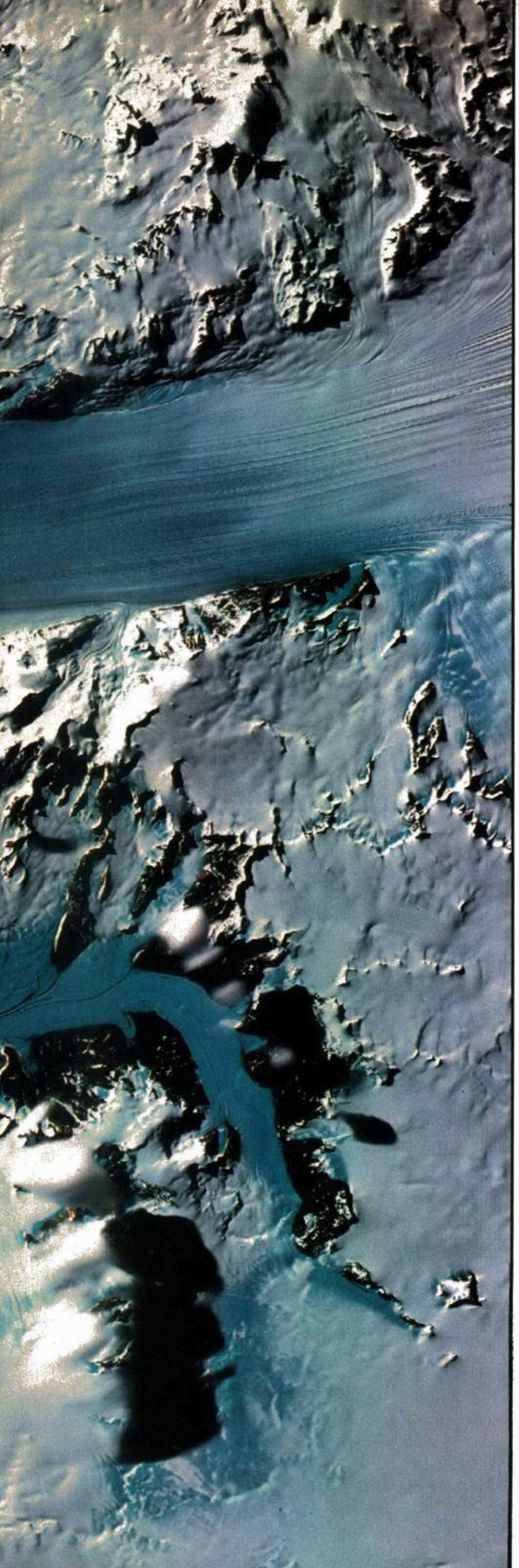




last 50,000 years or even, say some, within the last 2 billion to 3 billion years. According to Pieri, "Even something as steep and massive as the San Gabriel mountains would be gone in a matter of millions of years" with the kind of erosion associated with rainfall on Earth.

"This active period on Mars was self-destructive," says Pieri. "What we see is the tail end of a very active epoch — the last gasp of this period." Pieri believes after an initial active period, when water flowed freely, a brief transition period took place as water froze. While the planet lost more and more of its atmospheric "blanket," it also became more quiet geologically. The planet finally lapsed into its current state, which is dominated by wind erosion.

Still another factor may have played an important role in the changing Martian climate: the formation of the Tharsis Bulge. Tharsis is a high plateau formed by some of the largest volcanoes in the solar system, including Olympus Mons. This vast plateau is about the size of the United States. Before the great volcanoes of Mars built the plateau, Mars may have tipped its polar axis toward the Sun by as much as 43 degrees. Perhaps 3 billion years ago the atmosphere became intermittently moist as the polar regions melted; rivers may have flowed on the surface. But the cold Martian atmosphere gradually became less dense. After the Tharsis volcanoes built up the plateau, thus dampening the planet's "wobble," the obliquity of the planet became less severe, so the poles seldom melted. Water became permanently frozen in the northern and southern regions and left a frigid, desert world of drifting sands.

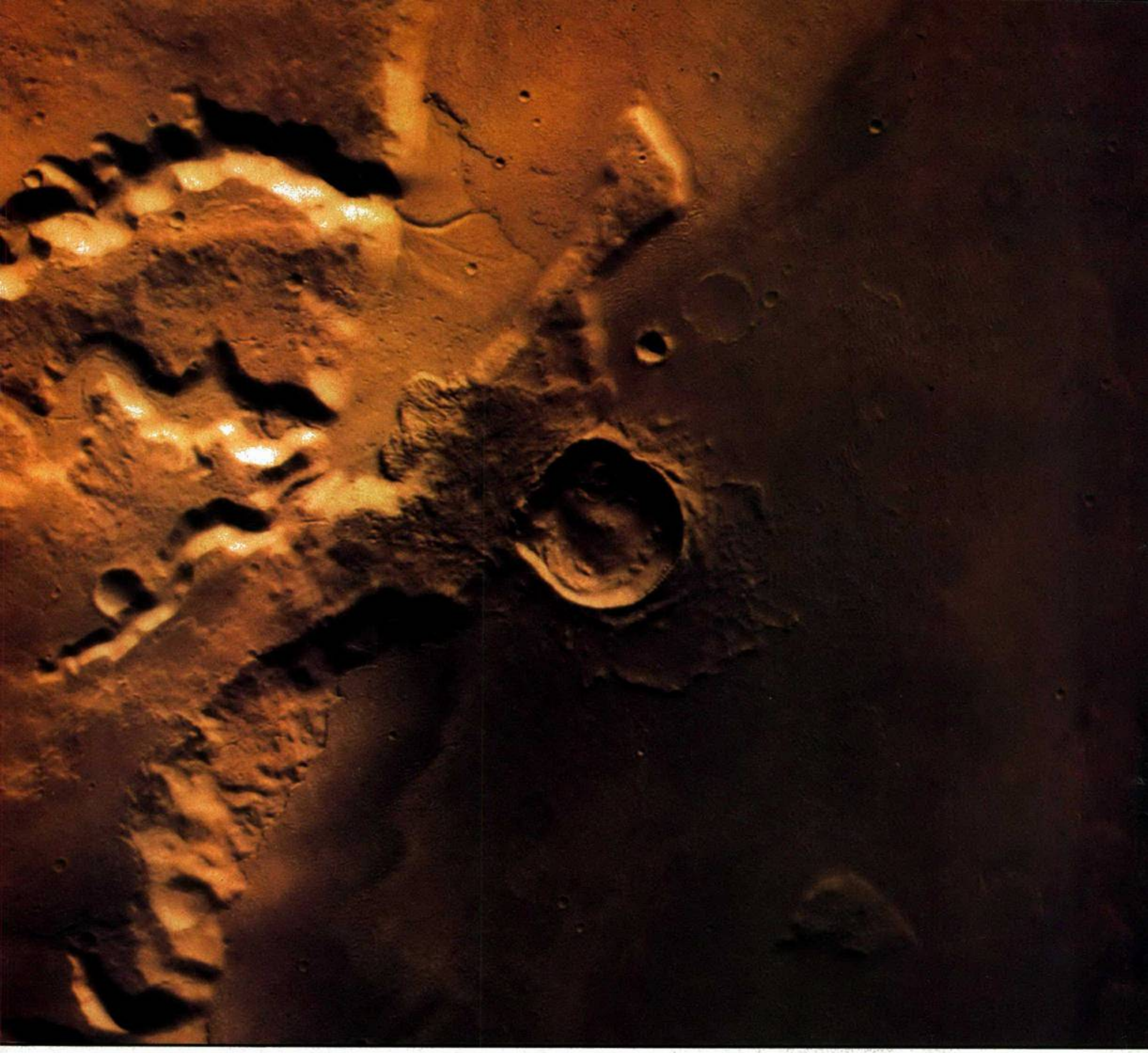
"A lot of people would like to believe that all the channels are ancient—that they happened, say, in the first billion years," explains Hal Masursky of the United States Geological Survey. "Unfortunately, the facts don't fit that. We have found small channels that have cut through lava flows, where we have gotten good crater counts." According to Masursky, the crater counts on these lava fields indicate the channels meandering through these areas range in age from only 0.5 billion to 3 billion years. In geological time this is very young, and it implies dynamic forces have been present on Mars very recently. Some of these small channels were apparently caused by subsurface ice; others, Masursky believes, may have been linked to some kind of precipitation. "Whether that means rain or some sort of snow, we just do not know."

But, Hartmann adds, precipitation is only one explanation. "At the time the Mariner 9 data was coming in, these dendritic [branchlike] networks implied widely distributed sources. The networks did not seem to emanate from a specific location but had all of these delicate networks over large areas. But then Sharp, Mizyon, and others pointed out that side canyons can develop from ground water sapping. There may be springs in the canyon walls that cause the wall to collapse. They eat away at the canyon in reverse, leaving a pattern similar to that of runoff."

The Telltale Signs of Water

Other researchers believe they see evidence of liquid water in Mars' distant past. "We see erosional and depositional features reminiscent of areas like Pleistocene Lake Bonneville [Utah]," says Pieri. "We see linear features that

Striations similar to those visible around the Martian crater in the photograph on page 15 can be seen in this image of the Byrd Glacier in Antarctica taken by the Landsat satellite. Photo courtesy of Baerbel Lucchitta, United States Geological Survey.



Above: A meteor impacting the once-icy crust in East Mangala Valles excavated this crater and created a two-lobed ejecta blanket. (This photo is a close-up of the crater on page 7.) Photo courtesy of Al McEwen, United States Geological Survey.

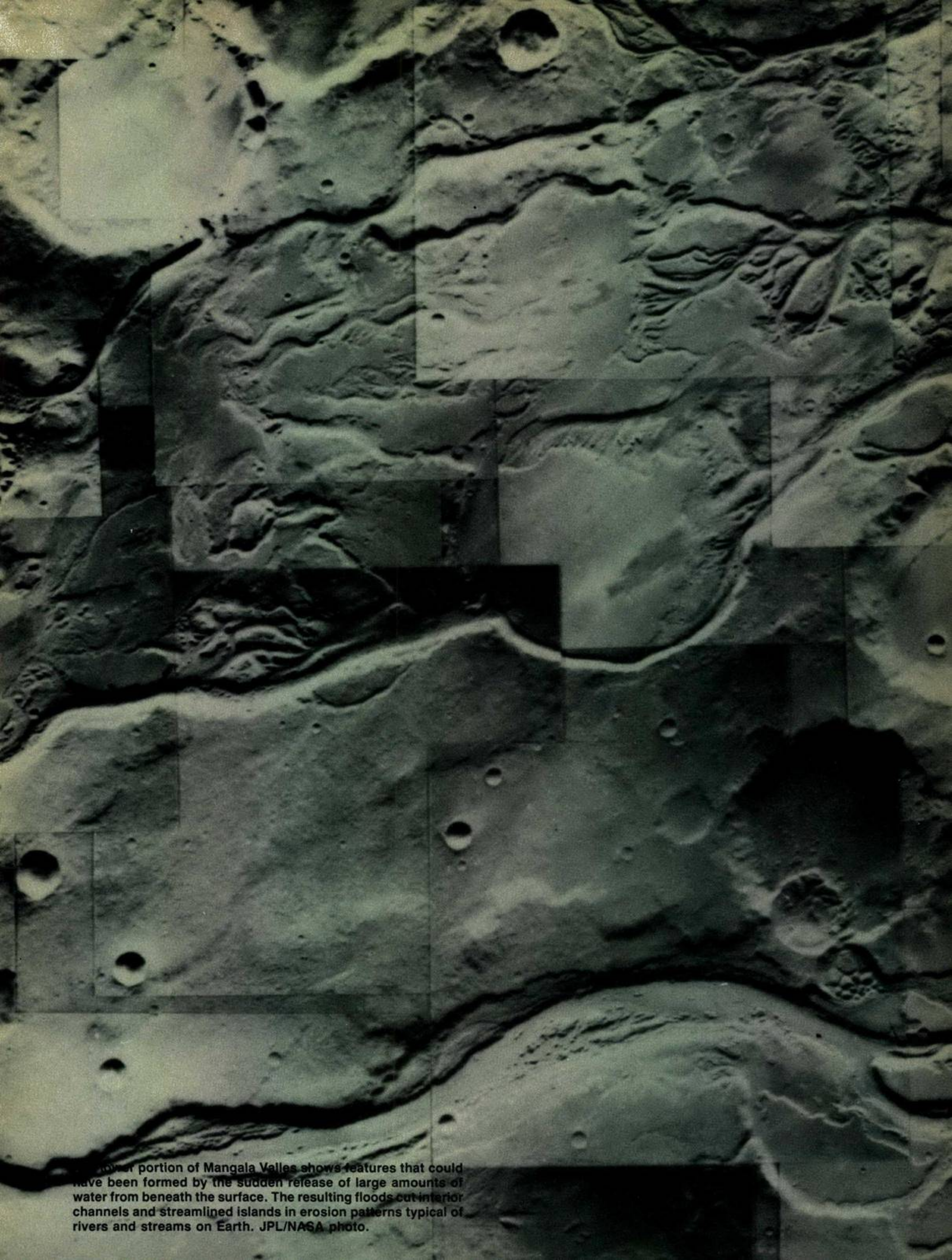
Opposite: Erosion features similar to those caused by ice or glacial flows on Earth appear in this mosaic taken by Viking Orbiter 1 from a range of 1,673 kilometers. Flood waters apparently flowed northward (from lower left to upper right), cutting through lava fields and flowing around craters. JPL/NASA photo.

we can trace for a long distance, and these features are really difficult to explain by means other than liquid water. There are formations that resemble spits, islands, and sandbars."

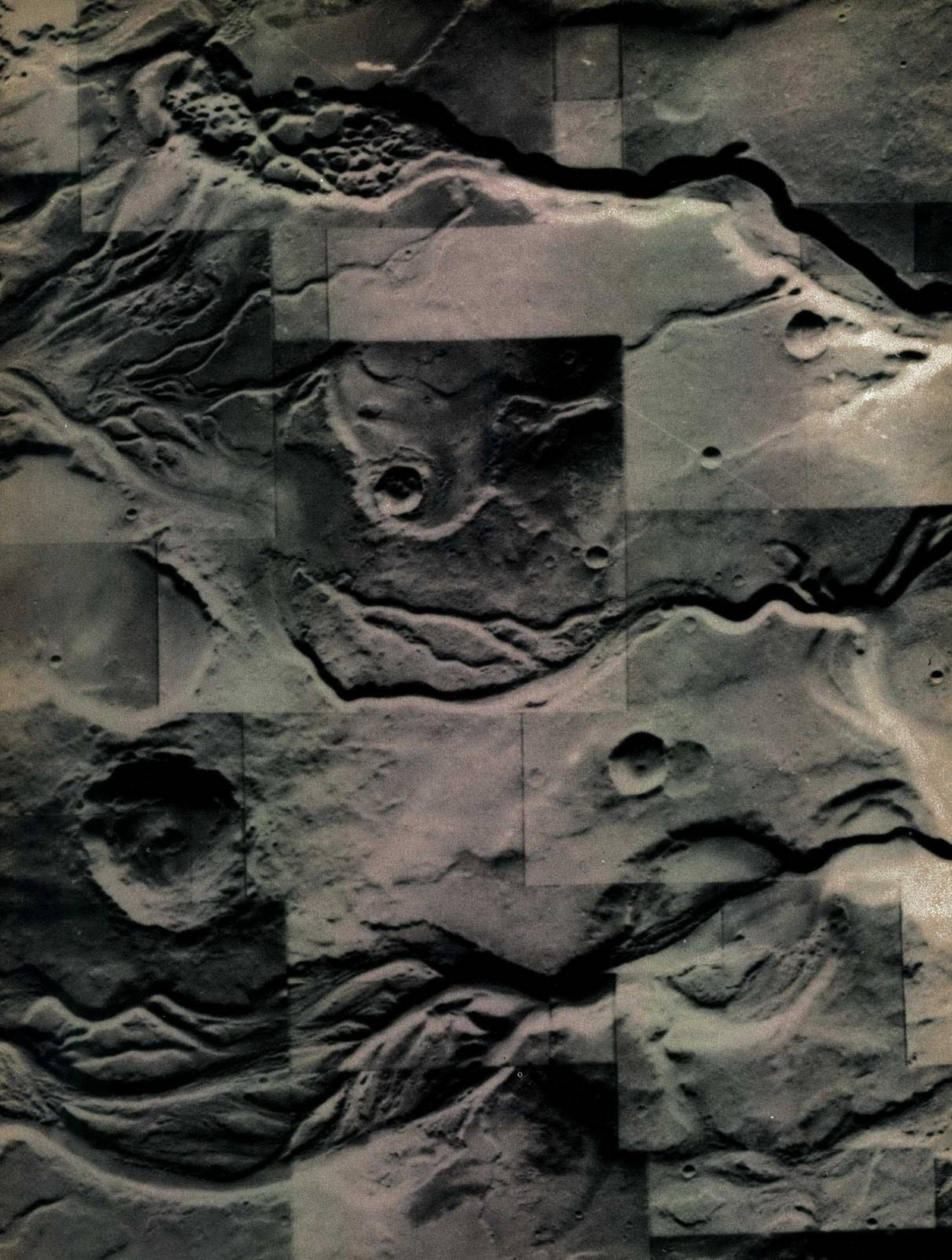
Thus Pieri describes certain areas on Mars he believes show ponds of water that once stood on the Martian surface and did not freeze. He points to the example of the scablands of Washington State, which reach into Idaho, Utah, and beyond. These areas were flooded when a great natural dam of glacial ice broke some 18,000 years ago. The scours and grooves that resulted bear striking similarity to areas on Mars. Looking at the morphology of these eroded patterns, Pieri says, "water had to have free-flowing boundaries. Perhaps there were ice blocks flowing along too, but the edge had to be liquid."

JPL research geologist Timothy Parker first noticed areas on Mars that looked very similar to the Lake Bonneville area, which he was familiar with from previous research. He now works on a team that includes Pieri and geologists Dale Schneeberger and Stephen Saunders. They are studying the evidence for liquid water on Mars and have recently suggested there was once an ancient shallow sea in Mars' northern hemisphere. This sea may have covered 15 percent of the planet's surface. (See AstroNews, December 1986.)

Their hypothesis was born out of a question: With all



[illegible] lower portion of Mangala Valles shows features that could have been formed by the sudden release of large amounts of water from beneath the surface. The resulting floods cut interior channels and streamlined islands in erosion patterns typical of rivers and streams on Earth. JPL/NASA photo.



the evidence of flooding on Mars, why are there no obvious alluvial fans (areas where floodwaters have deposited sediments)? Parker's team assumed these sediments would be seen in different forms if they had been deposited in an existing body of water. They searched for such features at the margins of lowland plains in Mars' northern hemisphere. "Sure enough," says Parker, "we found them all over the place."

They found curved ridges marking the boundary of the smooth lowland plains and the cratered uplands. The concave sides of these ridges face toward the plains and have the same distinctive shape as coastal barriers linking islands on Earth. These ridges resemble tombolos (sandbars connecting several islands) and are of comparable size. Several sites even appear to show the junction between two flowing currents of shallow water. Additional evidence, says Schneeberger, lies at the base of cliffs and knobs in the same areas.

"The shape of the profile of these areas is not from usual erosion," he says. "Instead of having a flat or concave slope at the base, its base is convex. We find these types of slopes along shorelines where wave action has deposited material over time."

Parker is quick to point out that Mars' hypothetical northern sea may have existed in different areas at different times and need not have been stable for very long at any given level. The Bonneville shoreline was only stable for approximately 4,000 years. Many different forces can cause geological formations, but Parker claims only two conditions can adequately explain all the features they see: glacial erosion or standing waters.

The four-member team admits this hypothesis might provoke controversy. In the conclusion of a recent paper they write: "While our assertions may appear provocative, they are consistent with very conservative estimates of Martian global water inventories, as well as with an emerging realization that thin, heavily sediment-laden flows may spread out from channel mouths across the northern plains for hundreds of kilometers."

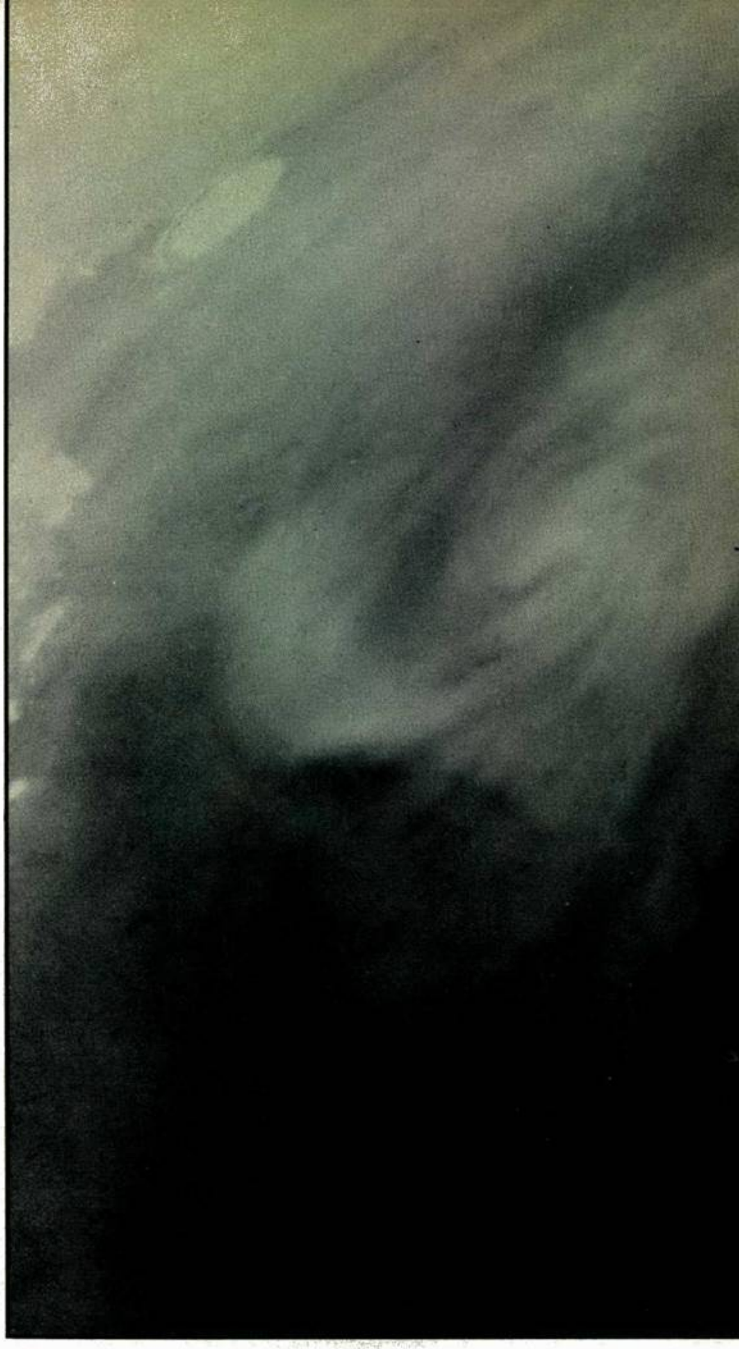
But other hypotheses have also been proposed for the mysterious missing alluvial fans. Geologist Michael Malin of Arizona State University has been studying the surface erosion of Mars since the Viking missions. Malin says the problem with interpreting Martian channels and valleys is deciding which erosional force did the eroding.

"Wind, water, and ice all behave like fluids," Malin explains. "Physics doesn't care which you use; it's just a matter of time. Where wind acts upon the surface in terms of meters per second, ice acts upon it in meters per year, and [liquid] water is somewhere in between. But the end result is strikingly similar, even to a person standing right there."

Malin believes the channels were formed, in most cases, by several agents over long periods of time. Initial valleys may have formed by flooding and then were expanded by subsurface melting, wind erosion, and other action.

"We find these valley networks all over the ancient, cratered terrain," says Michael Carr. "They may be due to many things: sapping, precipitation, or some tectonic origin. Under certain conditions [i.e., during certain stages of the Martian orbit] we find that water may migrate from the poles to lower latitudes. The water may be deposited as snow, which then causes these valleys."

Carr takes issue with the idea that water has flowed freely across the Martian surface for extended periods. "If there is liquid water, it freezes very quickly," he says. "Open bodies of water in the past are very unlikely." Even large lakes, if they were to exist for any period, would be covered by a thick crust of ice, according to Carr's calculations. But once in the form of ice, the water could remain for long periods.

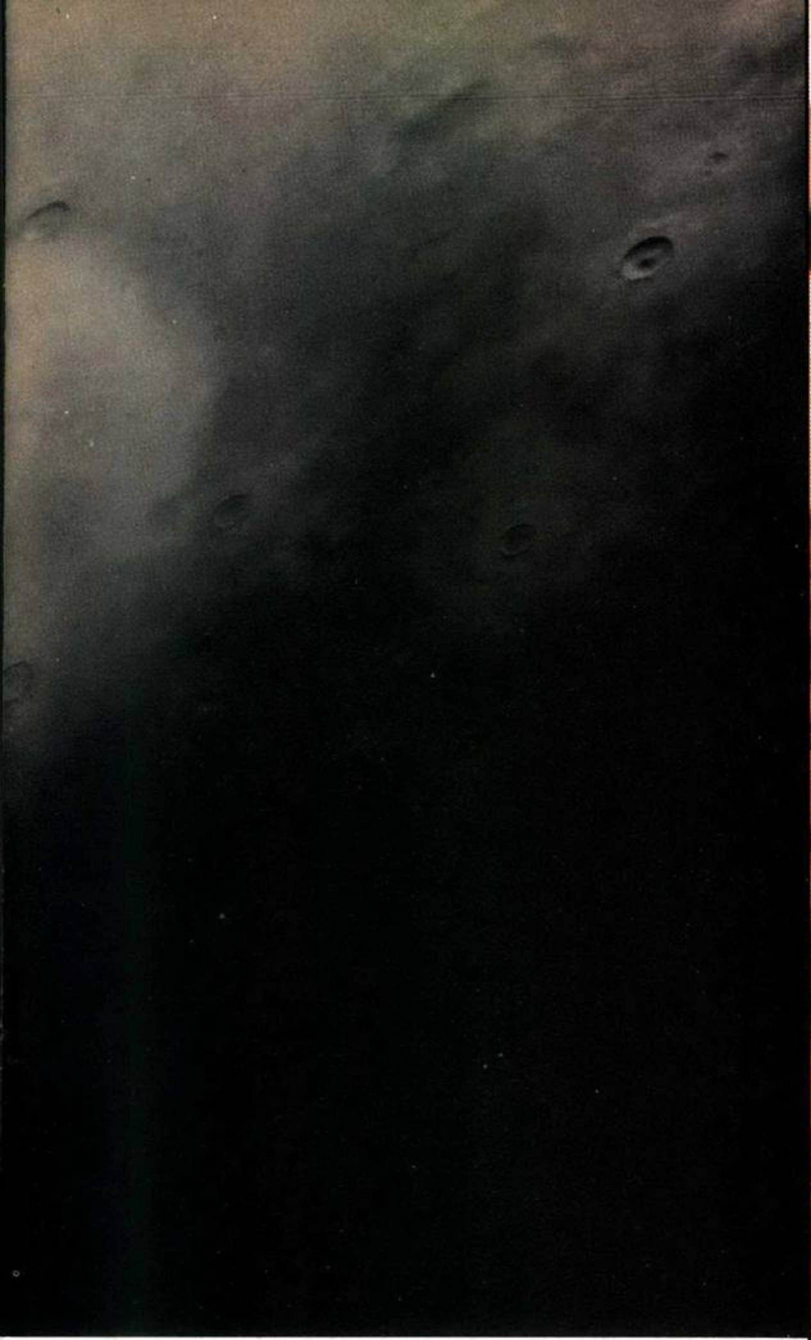


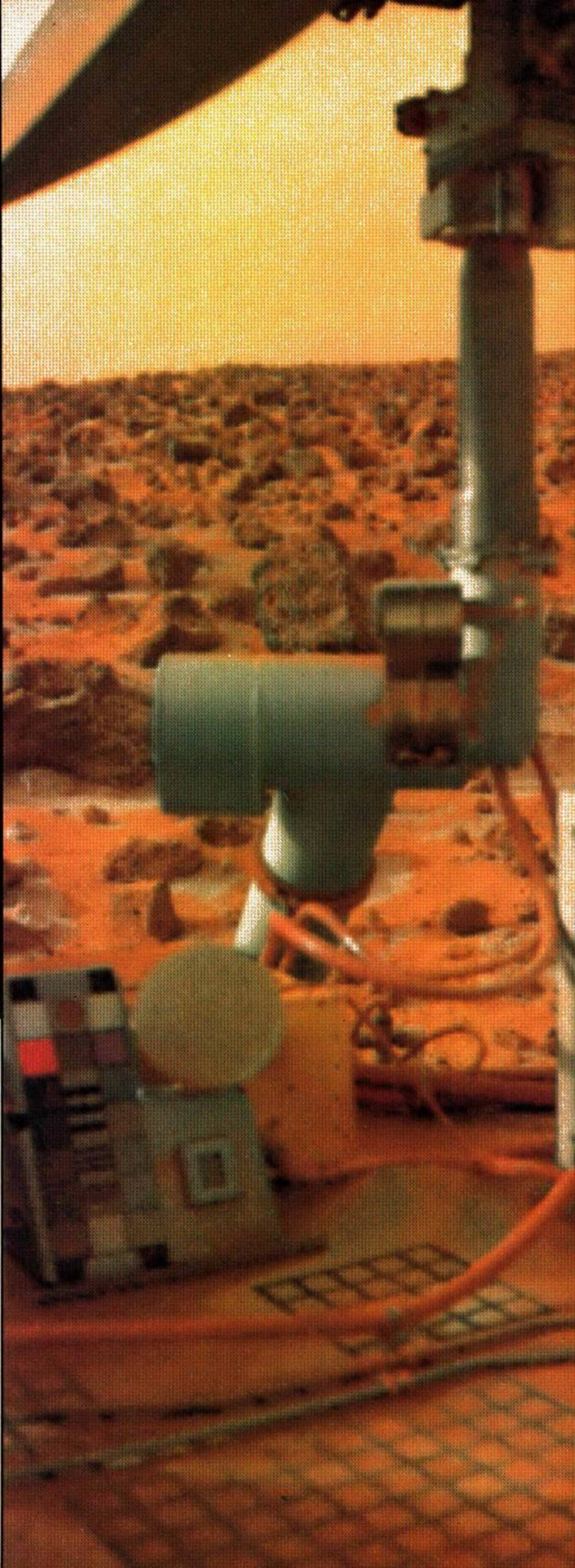
The Role of Martian Glaciers

Ice flows, in fact, have been cited as a factor in many eroded areas on Mars. Baerbel Lucchitta, a geologist at the United States Geological Survey, has done research she believes supports the proposition that ice has been the driving erosional force in many of Mars' channels.

"Theories that suggest erosion by flood, mud, or ice rely primarily on morphologic similarities between features recognized in Martian channels and those seen in flooded or glaciated valleys on Earth," she wrote in 1982. "Among the various erosional agents, only ice produces many morphologic analogs at similar scales on both planets."

Lucchitta points to areas on Mars that have very little slope but show strong scour patterns. In some cases Viking



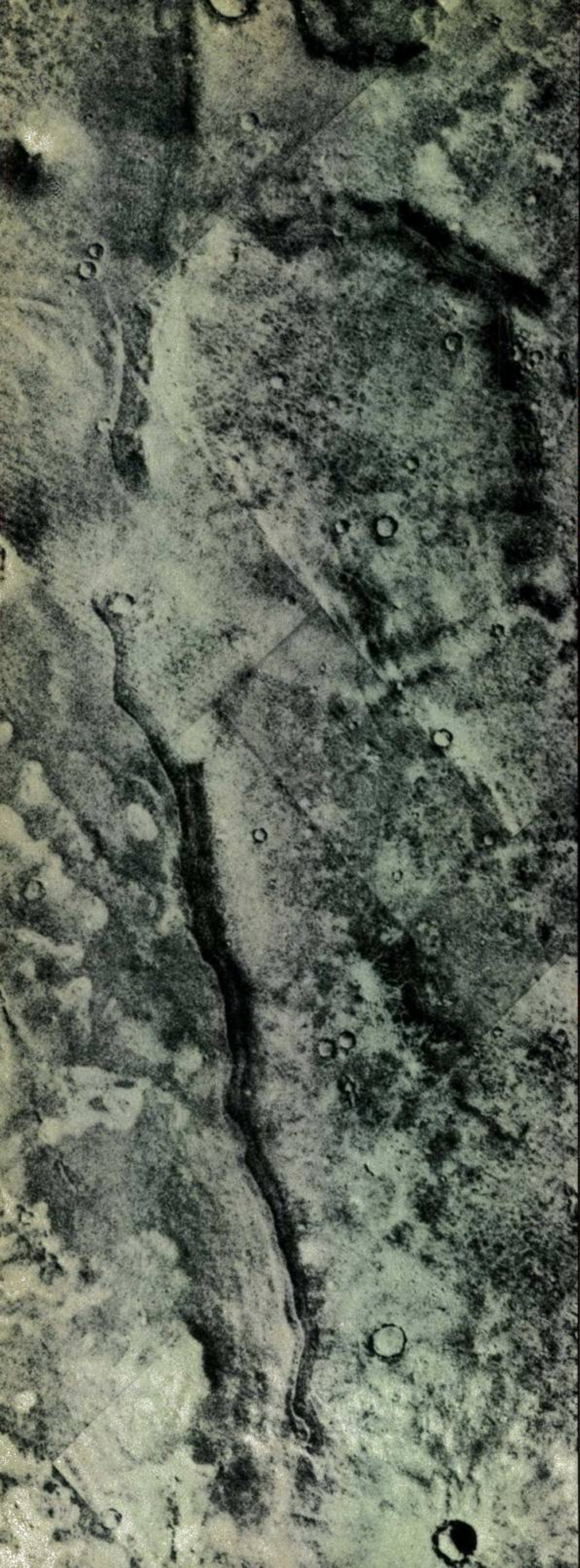


Above: A cyclonic storm pinwheels across the northern Martian desert. Temperatures measured by the Viking Orbiter indicate this is a cloud of water ice, not carbon dioxide. In the upper left, ice-filled craters mark the border of the north polar ice cap. JPL/NASA photo.

Right: During Martian winter in the northern hemisphere Viking Lander 2 photographed a thin layer of ice that remained on the surface for approximately one hundred days. JPL/NASA photo.

data shows these erosional patterns may actually flow uphill for many miles. "Low ground gradients are no deterrent to glacial movement on Earth, however," she writes. "For instance, the Wilkes subglacial basin in Antarctica has a gradient of essentially zero [it is level] for nearly 2,000 kilometers. Ground gradients apparently are not a critical determinant for glacial motion; indeed, glaciers are known to move uphill under certain circumstances." According to Lucchitta, one major advantage of the glacial theory is that the features in question are in the correct scale for comparison with their terrestrial counterparts.

Above: This portion of Chandor Chasma, located in the central region of Valles Marineris, may have been carved by huge lakes that deposited sediments in the form of flat-topped mesas. Photo courtesy of Al McEwen, United States Geological Survey.



Left: Can you see a shoreline against a cliff running vertically through this mosaic of high resolution Viking photos? Several Viking geologists believe the land to the left of the dark shoreline is higher. A canyon extends to the right of the shoreline that geologists suggest was partially filled with water 2 billion to 3 billion years ago. JPL/NASA photo.

Hal Masursky contends the most spectacular glacial features appear at the beginning and end of the glacier. He claims we see none of these features on Mars. But Lucchitta responds that such features are characteristic of mountain glaciers, but not of ice sheets and streams. "The ice sheets in Antarctica, for example, don't have well-defined moraines because they meet with the ice shelves. This is only one possible explanation," Lucchitta said.

Although no source for the ice flows has been found,

the same is true for the water. Additionally, the actual mechanics of erosion and transportation of material by glaciers is still poorly understood. Most studies have been done in fairly temperate areas where interglacial water flow and certain aspects of heat generated by shearing (the stress caused by the sliding motion of a glacier) are understood. Glaciers in subpolar or polar regions behave differently and have not been studied as extensively.

If glaciers did play a part in Mars' history, they were probably most like glaciers in Earth's polar regions.

"The general morphology is not what you would expect," says William Hartmann, "but, on the other hand, a lot of people are coming around to ice as a major factor [in Martian erosion]."

Retrieving a Piece of the Puzzle

In the final analysis, crucial gaps remain in our understanding. The dynamics of water and ice flows in the low Martian gravity are not yet understood. Better valley profiles, gradients, and other topographic data are needed before models of Martian erosion will be useful. As the late Tim Mutch, leader of the Viking lander imaging team, put it: "In reasoning by analogy we are constrained by our own experience. The number of analogies at our disposal is a function of our knowledge of terrestrial landforms. If processes on Mars produce unique forms, then dependence upon analogies may blind us to that uniqueness."

Future missions to Mars may shed much light on the role water played in shaping the topography of the planet. In 1988 the Soviet Union will mount its most extensive exploration of Mars to date. Two orbiters carrying sophisticated instruments will observe the Martian surface while two "hopper" probes will explore the surface of the moon Phobos. The hoppers will spring from one area of Phobos to another, photographing the surface and gathering other information about the tiny moon.

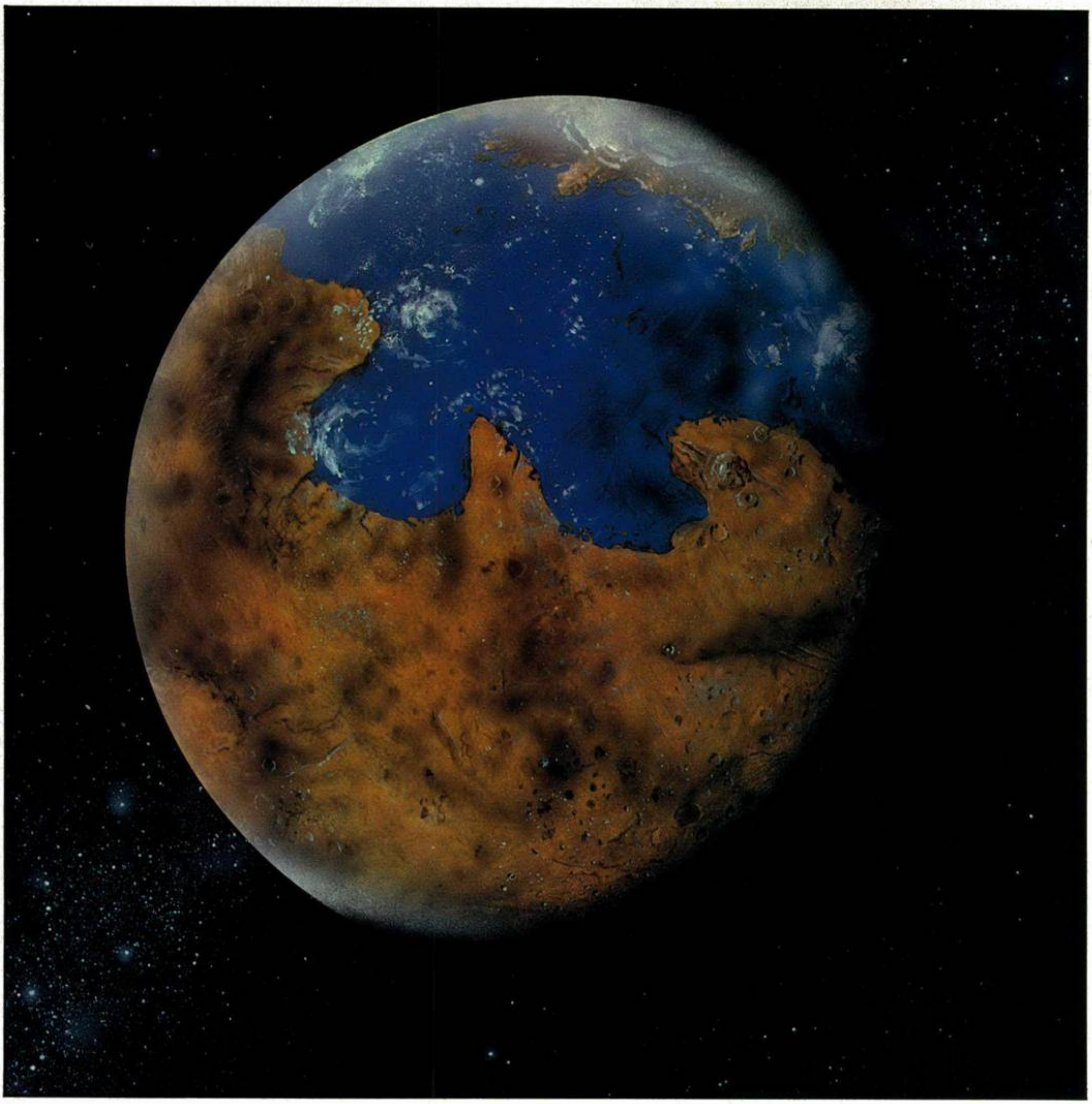
Although no specific launch date is yet scheduled, the U.S. Mars Observer Mission should get under way by 1992. The orbiting spacecraft will take very high resolution images of the surface, map water vapor, and perhaps detect water within the upper layers of the Martian soil. This detailed geological mapping will give scientists a better understanding of the makeup of the Martian surface.

Many mysteries of Mars' history, climate, and water remain locked within the soil of Mars. The best way to shed more light on these dark areas is to examine Martian soil firsthand. Though planetary scientists are divided over many of the specifics of Mars' past, they are nearly unanimous on one point: the logical step following the abovementioned Soviet and U.S. Mars missions is a sample-return mission. But a sample-return mission would be incredibly complex, involving at least one orbiter, a lander, a rover, an ascent vehicle, and an Earth-return spacecraft. Many details need to be worked out, but a general scenario follows these lines.

The lander would touch down on the surface of Mars in a relatively safe, flat area. It would immediately scoop up a contingency sample of soil in case an emergency launch was required. The soil sample would be photographed and then stowed aboard the ascent vehicle. For the next several months a rover would roam the rusted landscape of the Red Planet, documenting each soil sample. At each site soil would also be tested by the rover and the data transmitted to Earth.

In addition, the rover would venture into rugged terrain, scoop loose soil, drill core samples, and chip rock. Eventually, the precious cargo would be returned to the lander and put aboard the ascent vehicle. With the rover a safe distance away, the ascent vehicle would lift off the planet, achieve Martian orbit, and dock with the orbiter. The orbiter (or a part of it) would then fire its engine to send itself homeward. After the samples of the Martian surface were in hand at home, scientists would continue to use the rover, perhaps sending it to even more exotic and dangerous places.

One important aspect of a Martian sample-return mission is the chance for international cooperation, most notably with the Soviet Union. Serious talk of a joint Soviet-American Mars sample-return mission occurred at the NASA-sponsored Mars Convention held July 1986 in Washington, D.C., and was even discussed during the Reagan/Gorbachev summit in Iceland last autumn. The Soviet Union has had much success in unmanned roving vehicles (recall the Lunokhod 1 and 2 rovers used for lunar exploration in 1970 and 1973) and could fabricate the rover part of the Mars vehicles. The United States could



A team of JPL geologists believe Mars may have once had a shallow sea that covered most of its northern hemisphere. The Syrtis Major plain and the Hellas impact basin can be seen near the limb of the planet at left; the volcanic plateau Elysium Planitia extends toward the evening terminator at right. Painting by Michael Carroll.

produce the lander and ascent vehicles. The only interface required would be the sample-transfer equipment and communications.

Other spacefaring nations could build additional parts of the spacecraft required for the complicated mission. Space exploration has been an area in which the United States and Soviet Union have had some success in cooperative ventures. Aside from cost sharing, this mission could greatly improve our understanding of Mars.

The face of Mars we see today has revealed itself to us grudgingly. It has tantalized us with mysterious bits and pieces of desolate landscapes: cratered plains, cloud-covered volcanoes, misty canyons, and, perhaps, once-flooded valleys. Like a planet-sized jigsaw puzzle, the pieces are beginning to come together.

Mars is neither the Lowellian world of desert oases nor the Moonlike world shown to us by the early Mariners. As the true face of Mars slowly emerges from the mists of our ignorance and the fog of our preconceptions, we gaze upon a new world full of promise: the promise of better understanding about our near neighbor in space, the promise of new insights into our own world, and perhaps even the promise of new cooperation and friendship with fellow human beings only half a world away.

Michael Carroll is a staff artist at the Reuben H. Fleet Space Theater in San Diego, California; co-chairman of the International Association of Astronomical Artists; and an avid space enthusiast. Two of Carroll's paintings appeared in the January 1987 issue of ASTRONOMY.

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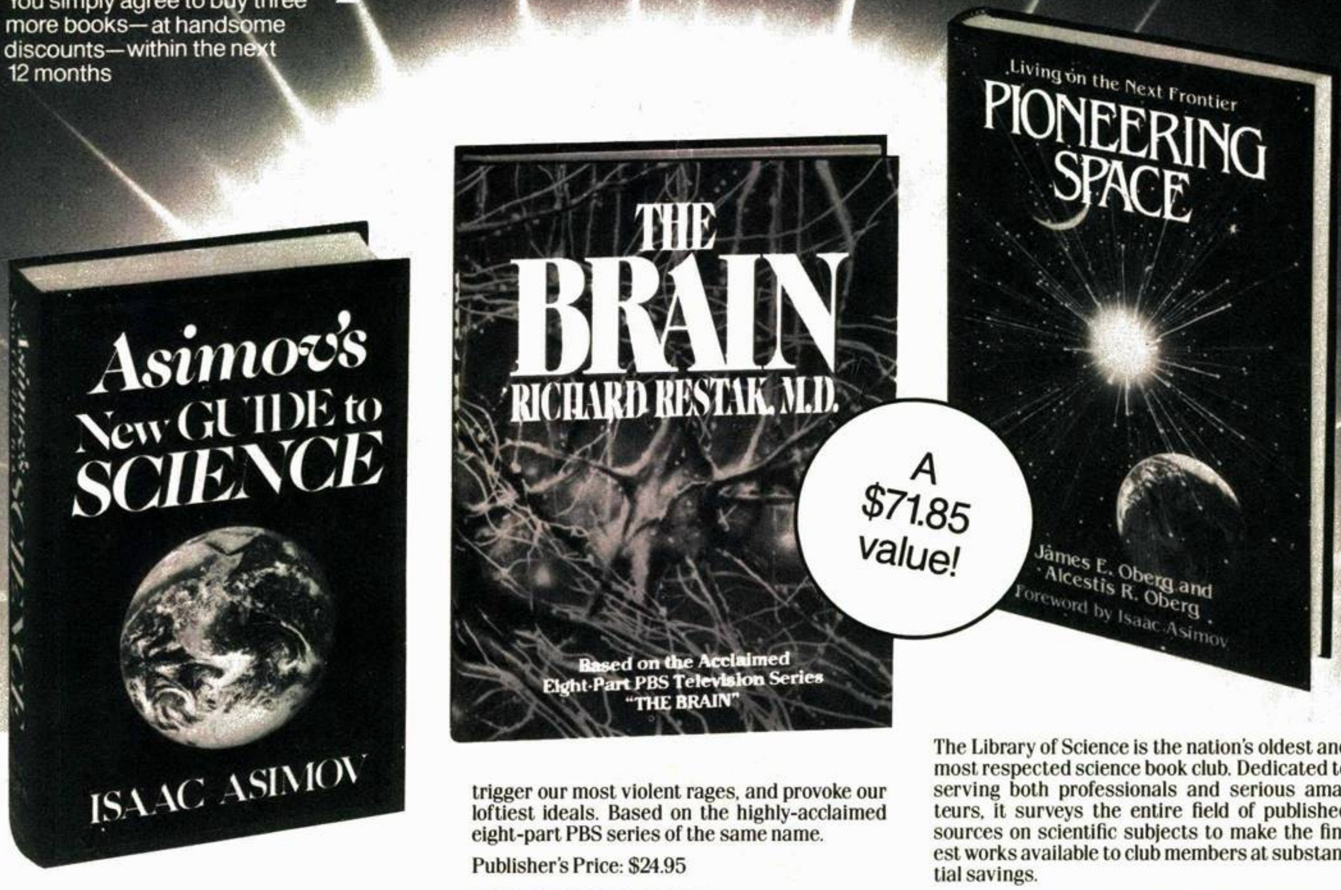
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ASTRONOMY
Forum

Halley in Heidelberg, Planets in Paris

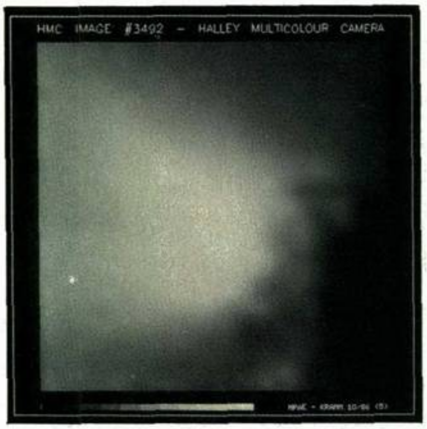
Nineteen eighty-six may long be remembered as the year planetary astronomers left America and headed for Europe. It was also the year Western Europe pulled off its first space spectacular — the Giotto probe to Comet Halley — and the year the Soviet Union unbent a bit and shared with the world "real time" data from two of its spacecraft, Vega-1 and Vega-2, as they flew past Halley.

In March 1986 I spent a week at the European Space Operations Center in Darmstadt, West Germany, covering the Giotto flyby. After two years of "The-Comet-Is-Coming"-type coverage of the all-too-famous comet, there was finally something new to say. In June ASTRONOMY reported the preliminary results from the Giotto and Vega missions and in September summarized the science reports the multinational science teams produced thirty days after the flybys.

But in the world of science, thirty-day results describe only the obvious, preliminary findings that have been derived directly from spacecraft data. The process of turning raw data into "knowledge" takes more time because it requires careful analysis, compensation for malfunctioning equipment, calibration of instruments, and — most crucial — time for the interaction of scientists in different disciplines: time to learn about one another's findings and interpretations of them, to talk, to kick around new ideas, to disagree with one another, and ultimately arrive at some new synthesis.

The products of this six-month-long period of gestation were presented in the Stadthalle of the ancient university town, Heidelberg, West Germany, at a special meeting on the exploration of Halley's Comet. Attendance was large — over four hundred comet scientists from around the world were there — and it promised to be scientifically productive and very exciting.

On October 27, 1986, Dr. Reimer Lüst, Director General of the European Space Agency, opened the Symposium. "Not much more than half a year ago we witnessed the encounters of a fleet of spacecraft with Halley's Comet," Lüst began, "but the comet did not live up to its reputation as a bad omen: all six encounters were highly successful. We also witnessed something else — the unprecedented worldwide collaboration in space involving not only the four space agencies engaged in the flyby projects but also a large community of ground-based astronomers." Citing the formation of the Inter-Agency Consultative Group and the International Halley Watch as the first tangible result of this collaboration, the early publication of the flyby results in *Nature* as the second, he concluded, "this Symposium is the third."



Giotto Image #3492 shows Halley's nucleus at high resolution. Image taken by the Halley Multicolor Camera, principal investigator Dr. H. U. Keller, © 1986 Max-Planck-Institute für Aeronomy.

"This collection of papers," said Lüst, with evident pride in his voice, "will represent the most complete description of Halley's Comet ever given." In my hand I held a book of abstracts 477 pages thick, each page containing a capsule description of research someone would present during the next five days. I had already pored over it for hours, trying to guess from the often cryptic wording which papers would turn out to be the most significant. And an important part of the symposium would be the publication of the Symposium Proceedings, a record, Lüst said "that will serve as testimony of our worldwide peaceful collaboration in 2061, when Halley's Comet reappears."

We had flown from Chicago/O'Hare via Keflavik, Iceland, to Luxembourg, eleven hours in the air tacked on the end of a busy Saturday, and had then driven to Heidelberg. The drive to Heidelberg was beautiful: the land was rural and rolling, the trees in the height of their fall colors, but my wife Eleanor and I were exceedingly tired when we finally pulled into the Atlas Hotel.

To my surprise we woke up early the next morning, feeling, if not refreshed, at least alive. After a nice breakfast we hurried along the Hauptstrasse toward the Stadthalle, where the meeting was to be held. The old city was paved in cobblestone, and even the newer parts of the city were tidy and meticulously maintained. The air was chilly, but the sun was shining and the city seemed fresh and clean, and all the shops were just opening. The sight of a huge model of the Giotto spacecraft in front of the red sandstone Stadthalle was a reassuring sign that we'd made it to the right place.

The first of the scientific papers that Monday morning was by A. A. Geleev of the Space Research Institute in Moscow on the interactions of Comet

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Halley with the solar wind. His presentation was crisp and fast-paced, comparing the theoretical expections with the plasma and magnetic field measurements made by Vega-1, Vega-2, and Giotto. Current theories are oversimplified, he said, approximations of the complex phenomena the probes actually found. He described each of the plasma structures in a comet: how neutral gas flows from the comet, where it ionizes, how the bow shock forms, and why a "pile up region" occurs some 10,000 kilometers in front of the nucleus. Though his talk was full of the jargon of cometary magnetohydrodynamics — "mass loading," "shock heating," "abiabatic approximation" — the thrust of the argument was clear: we understand the big picture, but not the details. "All of the spacecraft saw the same boundaries," he said, "but the fine structures are still a problem."

All morning scientists presented results from the flybys. Marsha Neugebauer of JPL, for example, presented some findings on protons from Halley based on one of the plasma probes flown on Giotto. Her paper was admittedly preliminary: "There's a lot of interesting physics going on in this interaction," she said, "which we hope to be able to tell you more about later." Alan Johnstone spoke of the perturbations in the solar wind flow upwind of the comet as it slowed under an increasing load of cometary ions and the plasma waves their interaction generated.

John Brandt and Mal Niedner of NASA/Goddard Space Flight Center discussed the sixteen major and ten minor tail disconnection events, showing that when a solar wind magnetic boundary crossed the comet, a disconnection event usually occurred. "Five out of six events fit our model," said Brandt.

We saw images taken in the light of ionized carbon monoxide, heard W. E. Celnik's analysis of the velocity that features drift down the tail, and watched a movie of CO_2+ features. "You can see the plasma streaming out of the comet," said Dr. Jockers of the Max Planck Institute for Aeronomy, gesturing at the big fuzzy picture on the screen above him, "then merging and flowing down the tail."

At lunchtime a number of us walked over to a little cafe for good German wurstsuppe and kasebrot. In the afternoon session the topic switched from plasma to gas, and the object of inquiry from waves and ions to composition and rates of production. The dominant molecule is water (80 percent of total cometary gas), while carbon monoxide makes up 10 to 20 percent, and carbon dioxide is 1 to 3 percent. Carbon-containing molecules comprise no more than 20 percent of the mass of the gas coming off the comet.

In these areas the ground-based and flythrough investigations complement each other. Ground-based astronomers scan the entire comet, explore it in detail with high-resolution spectroscopy, and monitor ongoing changes in it; the spacecraft zipped in, took a "snapshot" of the chemical composition, and zipped right back out. One important result was that the abundance ratios of important isotopes — C^{12}/C^{13} and N^{14}/N^{15} — are the same for Halley as they are for the Earth and the rest of the solar system, strong evidence that comets formed from the same primordial stuff the Sun and the planets formed from.

From the ground-based astronomers we heard over and over about Halley's variability. In the infrared the comet could drop three magnitudes in just a few days, and it doubled in brightness for a few days following an outburst on January 10. From their spacecraft data the Japanese reported the whole coma pulsed regularly with a period of 54 hours. Giotto saw rapid variation in the distribution of water ions; ground-based observers in South Africa saw structures that changed in a mere twenty minutes. Between the two Vega flybys the comet's gas and dust emissions changed significantly, and both Giotto and the Vegas detected rapid variations in the dust density as they flew through the comet.

Some of this variability comes from the increasing heating of Halley's nucleus as it approached the Sun. Some of it comes from intrinsic causes: pockets of ice or gas bursting through the cometary crust from the interior of the comet. And some of it comes, presumably, from the rotation of the nucleus. On Wednesday afternoon a volcano of scientific controversy erupted when Robert Millis of Lowell Observatory reported that photoelectric photometry of the comet revealed a clear 7.4-day periodicity, rather than the 52- to 54-hour period of rotation most astronomers had come to accept.

Ian Stewart of the University of Colorado then reported that ultraviolet observations made by the Pioneer Venus spacecraft orbiting Venus had also detected a seven-day cycle in the comet's rate of gas production. Michel Festou of Besancon Observatory then reported that measurements of the inner coma made as Halley brightened showed a seven-day variation, and the the amplitude of the variation had increased as Halley drew nearer the Sun. "We are combining data sets to get a period of approximately 7.4 days," he claimed.

Everybody, especially ground-based observers with long runs of data, scrambled to look at his raw data to see what he had missed.

Then came a dissenting voice. Mike Belton of the National Optical Astronomy Observatories had observed the brightness of what he thought was the bare nucleus of Halley when it was farther than 5 AU from the Sun, when the nucleus itself was the dominant source of light and when the complicating effects of the coma were absent. He obtained a double-peaked light curve with a period of 54 hours and 7 minutes. The double-peaked curve is just what you'd expect from a peanut-shaped object tumbling end-over-end in sunlight.

But the seven-day variation was undoubtedly real too, with many lines of evidence showing it. The big question was: Does the rotation of the nucleus cause it? The Vega imaging team felt strongly: No. Vega's pictures of the nucleus were completely incompatible with a seven-day rotation period and were compatible with a 54-hour rotation period. No question about it. They would show proof positive on Friday.

Plasma, gas, and dust papers were mixed in a complicated fashion from Monday through Thursday, while Friday was reserved for the nucleus. And Friday was the day we'd all been waiting for. The air was electric: people were excited.

The morning began with a review paper by Fred Whipple, who founded serious cometary astronomy, summarizing what we now know about the nucleus. Halley has a single nucleus, a discrete nucleus, not some flying pile of sand, and the nucleus is large — 16 by 8 by 7.5 kilometers. And it's a dark body, reflecting 4.5 to 5.0 percent of the visible light that strikes it.

Halley's mass lies somewhere between 5×10^{13} and 13×10^{13} kilograms, estimated from the "rocket effect" of evaporating gases on the comet's orbit. The volume of the nucleus is 5×10^{11} cubic meters, which means the density lies somewhere between 0.08 and 0.24 grams per cubic centimeter. Whipple went on to justify this number with other lines of research, concluding finally that the density almost certainly lies under 0.4 grams per cubic centimeter and over 0.1 g/cm^3.

Following Whipple's talk the morning paper session was devoted to the imaging results from the Vega and Giotto missions. A senior Russian scientist, G. A. Avanesov, went first, describing the two Soviet flybys. "The most useful images were taken plus and minus ten minutes of the closest approach," he said, "giving us about seventy good images to process." Work on these images is still under way, but the Soviet program is quite

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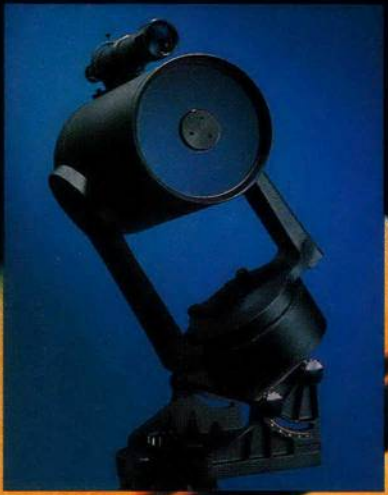

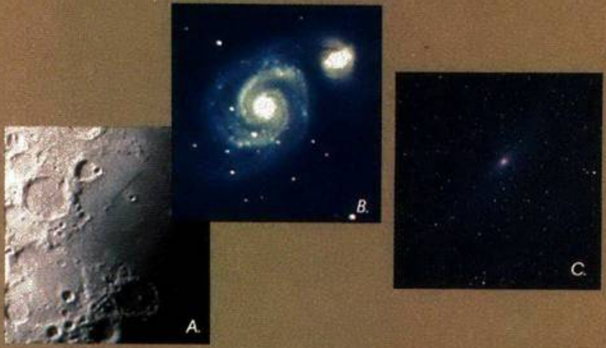

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Contact your nearest Bausch & Lomb dealer, or contact us direct at: Bausch & Lomb Astronomical Telescopes 135 Prestige Park Circle • East Hartford, CT 06108 • (203) 282-0768 ambitious. The Russians are constructing a three-dimensional model of the nucleus and a cross-sectional view of Halley's inner coma using the same techniques CAT-scanners use for medical imaging of the human body.

I had seen the Soviet image-processing display in the poster room and spent considerable time talking with the Russians there, even though they only half-understood what I said and their English was non-idiomatic at best. In any case, they let me photograph the monitor of their Halley image graphics system to my heart's content.

The next speaker, V. A. Shamis of the Space Research Institute in Moscow, described the image-processing techniques the Russians were using on the images. After processing them in the spatial frequency domain to remove instrument effects and electronic noise, the images were placed in a video data bank for scientific processing. "The big problem," said Shamis, "is limb detection. We use the second derivative of brightness, but the reliability of this technique still remains to be confirmed.

At the time the Vegas flew past Halley, the nucleus was very active, so it was enveloped in a cloud of dust. The problem was to locate the nearly invisible limb profile within this hazy cloud and to outline it. The Russians also had routines to enhance the visibility of the nuclear jets. "You can see some faint surface features," he added, "but I don't like to give recommendation of them."

V. I. Tarnopolsky discussed the reconstruction of the three-dimensional form of the nucleus. "Vega-1 made three images per minute and Vega-2 made one image each 100 seconds. We can construct the three-dimensional shape because the change in the line of sight was 160 degrees." Each picture defines a cylinder; the intersection of all the cylinders is the shape of the hard nucleus. Tarnopolsky's work had produced the best Soviet computer graphics I saw: the nucleus slowly rotating on the computer screen. His reconstruction of the three-dimensional structure of the inner coma was also quite striking. "It's like Russian dolls," he said, "one body inside another."

Brad Smith, best known for his work on the Voyager Team and now a member of the "Vega imaging team," presented two papers on the Soviet images. In the first he had followed the nuclear jets back to their source regions on the nucleus, using eleven of the best images from Vega-2, and they all lay on a line running across its daytime side. In his second paper he showed the photometric profiles of the most detailed Vega-2 image and concluded: "There's absolutely no doubt we are seeing the nucleus."

Other speakers presented further analyses of the images, deriving figures for the volume of the nucleus (375 km^3), its reflectivity (4 percent), its shape ("not a peanut, but an avocado"), and the orientation of its spin axis ($b = -64$, $l = +22$). Altogether it was an impressive display, not only of the sheer mass of information the Russians had extracted from their fuzzy-looking pictures, but also of how widely they had shared their data.

The movers and shakers of the Giotto mission (left to right): David Dale, project manager; Dr. Rudiger Reinhard, project scientist; Dr. Reimar Lüst, Director General of ESA; Dr. H. U. Keller, camera principal investigator; model of the nucleus of Comet Halley; Prof. Roger Bonnet, ESA director of scientific programs; Dr. E. A. Trendelenburg, former ESA director of scientific programs; and Dr. Fred Whipple, "father" of modern comet research. Lossen photo.

After coffee break the Giotto imaging team began its presentations. Dr. H. U. Keller, principal investigator of the Halley Multicolor Camera, presented the overview paper: Giotto flew within 605 kilometers of the nucleus, carrying a spin-scan camera that produced one image set per rotation of Giotto. The camera began operating half an hour before closest approach, at a range of 120,000 kilometers; it stopped operating twelve seconds before closest approach. Near the time of closest approach, it obtained sixty-nine fully calibrated color image sets with a resolution of 74 by 74 pixels. The resulting images showed a single, solid nucleus approximately fifteen kilometers long, shaped like a peanut with an extremely dark non-volatile crust.

Harold Reitsma from the Ball Aerospace Systems Division, an American collaborator on the HMC team, spoke on the processing of the images and gave the audience a quick analysis of the close-approach images, showing frame after frame, pointing out the sharply defined terminator on frame #3472, and the "crater" feature and a hill past the terminator catching the rays of the Sun on frame #3481. Because the camera automatically tracked the brightest part of the scene as Giotto approached the nucleus, the camera had tracked the brightest nuclear jet and recorded a smaller and smaller area of the nucleus. Frame #3493 still shows part of it, with small lumps and bumps on the surface, detail inside the "crater," and multiple subjets within the main jet. What I took to be the last frame, #3498, shows only the fuzzy glow of the brightest jet.

More stunning than the individual frames, though, was Reitsma's composite image showing the entire nucleus at low resolution, with more detail in the regions imaged in high-resolution frames. Unfortunately, though these frames were screened briefly for the audience of scientists, they were not released to the public. I asked Reitsma when they would be. "Two or three months," said Reitsma, "in two or three months they'll probably make copies available."

Listening to the afternoon papers was a heady experience — a bit like being drunk on comets, which, indeed, we all were. What sort of internal structure and composition could explain the observed properties of the nucleus? How and where could such a body form? Various models were bandied about: the icy conglomerate model, the fractured rubble-pile model, the macropore model.

All of the models supposed a non-uniform interior. In one case it was

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filled with fissures, and in another with regions that would vaporize differently. All of the models faced processing cometary ice into a hot, hard, black crust, which some accomplished via cosmic ray exposure in deep space, while others relied on exposure to solar radiation to do the job.

The debate over the rotation period surfaced again, with the imaging people tending toward a 52- to 54-hour period because it fit in with the Vega images and longer periods didn't. But the seven-day period wouldn't go away and seemed to draw its strongest supporters from the ground-based astronomers. But a new possibility emerged: nutation. Just as a spinning football wobbles in a bad pass, so might the nucleus wobble, or nutate. Jack Lissauer, a young astronomer from the University of California at Santa Barbara, spent a good part of Friday afternoon pitching a large squash he got from a vegetable market into the air, showing people how nutation worked. Halley's nucleus, which had been called a potato, a peanut, or an avocado, had now become a squash!

The meeting broke up late that evening. As I trudged back through the cold wet streets of Heidelberg to my hotel, I felt very tired. My feet hurt from standing, my back ached from sitting, and my light jacket was nowhere near warm enough. Still I felt excited, glad to have come and shared even a little bit in the exploration of another new world.

We didn't leave Heidelberg right away, but instead spent a rainy Saturday morning exploring Heidelberger Schloss, the great castle on the hill overlooking the city. The brilliant autumn leaves glistened, and fog rolled down the valley. It was great. Ele and I studied our maps — which was the best way to Paris? Should we drive south a bit or make a run straight east to the border? We decided to detour a bit, heading for Baden-Baden at the edge of the Schwartzwald, and stayed in a little place with a rushing brook across the street. On Sunday we crossed into France.

The annual meeting of the Division of Planetary Sciences, a branch of the American Astronomical Society, opened at 9 a.m. Tuesday, November 4, with a hearty "Welcome to Paris" from Andre Brahic, chairman of the Scientific Advisory Committee for this year's papers, and welcoming remarks from the DPS officers. Directing his comments to the contingent of European astronomers attending, DPS president Joe Veverka's greeting underscored reasons for meeting in Paris: "We are especially happy to be here so shortly after your great space exploit, Giotto, and happy to be able to tell you the findings from our spacecraft Voyager."

Andre Brahic responded warmly on behalf of the Europeans: "We look forward to future cooperations in space," adding that such international ventures were one way to have more money for fundamental research. Catherine de Bergh, who served as chairman of the local organizing committee, said she hoped many of the Europeans would "get addicted to DPS meetings" and attend them even when they were held in the United States, as they usually are.

There was an awful lot on the DPS agenda. This first day would be devoted to Uranus and the satellites of the outer planets. Wednesday was the day for the rings and satellites of Uranus. Thursday had papers about comets and asteroids, and Friday, still more on comets, plus Mars, Pluto, and Venus. Usually there were two sessions, and sometimes three, running parallel, so I often found myself hopping back and forth from one session to the other.

The first speaker was Brad Smith, this time in his role as head of the Voyager imaging team. "Voyager," he began, "is perhaps the most successful space mission ever flown, but we should bear in mind that it is now a rather tired and worn-out spacecraft." He skimmed over the engineering effort necessary to keep it operating, then turned to his first slide, a clearly labeled diagram showing Uranus and its orbit. "This is the south pole," pointing at the pole currently facing the Sun, and slightly south of the ecliptic. "And this is the direction of rotation."

With Uranus the identity of the north and south poles has been confusing. Several years ago the International Astronomical Union declared the pole that used to be called the north pole would now be called the south pole, and vice versa. North would be defined as the pole north of the ecliptic, rather than the pole defined by the rotation-determines-name-of-pole rule used previously and apparently still used by some workers in Europe. "I just wanted to get that straight," he said.

He then launched into a whirlwind review of Voyager's findings: the rotation period (17.25 hours), the reddish and hot polar regions, the prograde planetary wind, the high magnetic field inclination (60°), the detection of aurora and discovery of electroglow, and the unexpected pattern of densities of the major satellites (1.6, 1.7, 1.5, and 1.5 g/cm^3, respectively).

In subsequent papers we heard the very best and most recent Uranus radii (R_{eq} = 25,559 km; R_{pol} = 24,970 km), the detailed thermal structure of the Uranian atmosphere and models to explain the backwards planetary wind system, the seasonal variations in the thermal structure, and so on. I decided to switch to the session devoted to outer planet satellites at that point and took in a series of papers discussing dome craters on Ganymede (Ganymede's ice is soft, so craters go flat in a few billion years), Ganymede's early history, how Io gets tidally heated, how bodies with dirty-ice surfaces gain heat ("you get a solid-state greenhouse effect"), the radius (200.1 km), density (1.14 gm/cm^3), and composition (30 percent rock, 70 percent ice) of Mimas, evidence for tectonism on Rhea, the optical properties of Phoebe, which suggest it's a captured asteroid, and the spectroscopic evidence that suggests Neptune's satellite Triton has seasons and liquid nitrogen and/or methane on its surface.

That evening we were all invited to a reception at the old Observatoire de Paris. The displays in the observatory were wonderful. I spent the evening examining the artifacts of three centuries of astronomical activity: old telescopes by Leon Foucault, mural quadrants, objective lenses with 200-foot focal lengths, and the fair-copy observing diary of one Charles Messier, written in his own hand.

I had a project in mind for Wednesday's lunch hour: to visit the office of the Societe Astronomique de France. The United States doesn't have a national astronomical society; France does. The problem was to find 3, rue Beethoven, because rue Beethoven didn't show up on any of the city maps I had. From the postal zone I knew it was within walking distance of the Palais de Congres. Finally, by asking lots of questions in my nearly unintelligible French, I found my way to a tiny street only one hundred meters long, practically on the Seine and across the river from the Tour Eiffel.

I knocked and entered, as the sign asked. It was the right place, with lots of neat books, star atlases, and slide sets for sale, but I can't speak much French and the folks there didn't speak much English. We smiled a lot and spoke to each other in very simple sentences, and I bought a number of books (I can read French, at least), took all their membership information, and promised to send them lots of AstroMedia stuff. I got back to the DPS just in time to hear Torence Johnson, Galileo project scientist, give a review paper on the satellites of Uranus.

That evening the DPS held a special session entitled "Future Planetary Missions." It had something previous

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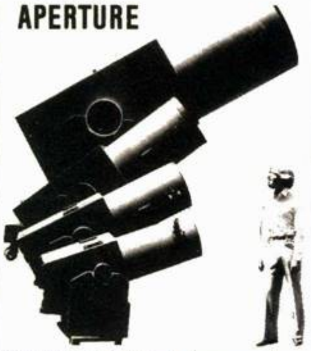

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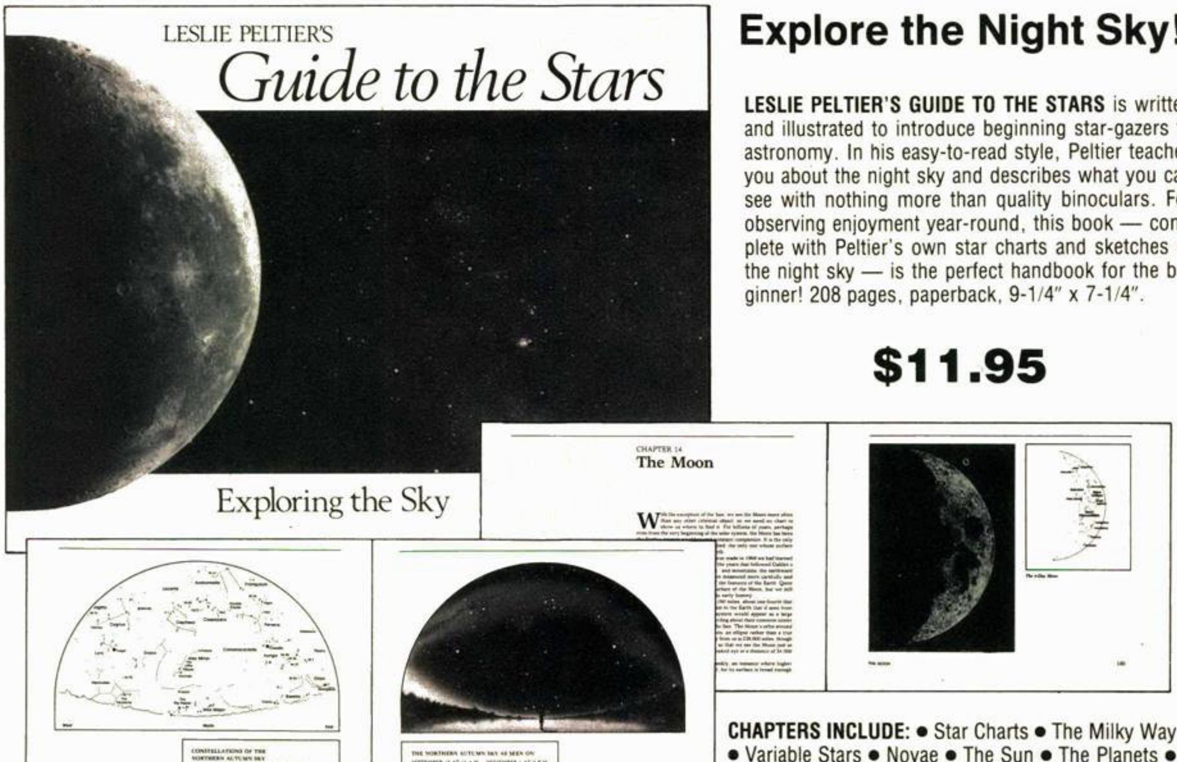

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special sessions have lacked: an international orientation, with reports from France's CNES (Centre National d'Etudes Spatiales) and Europe's ESA (European Space Agency), as well as from NASA. Every one of the Americans present knew the chaotic state of NASA's plans and the many conflicting priorities that could delay important planetary missions another two, three, or even five years or cancel them altogether. Among the American scientists I sensed a deep distrust of NASA's funding policies and a cynicism that, seldom voiced openly, came out mainly in whispers.

But NASA's Geoff Briggs was optimistic, promising that his office, the Office of Space Science, would mount a campaign to get "a real honest five-mission effort" from NASA. "What [our current planetary program] boils down to," he said, "is the missions we already have on our books plus a comet mission, Cassini [to Saturn and Titan], and a possible Mars mission."

"Our budget is known and predictable for a long time to come," said G. Haskell, the representative of the European Space Agency, contrasting ESA's fiscal position with that of NASA, "but the drawback is that it is a relatively small budget." He outlined the cornerstones of ESA's philosophy: to work in space astronomy and solar/terrestrial physics in a funding environment that is rigid in its commitment to funding yet flexible enough for new ideas to be introduced.

"Years ago there was a decision not to enter into planetary science, but it's now become a quarter of our total effort," he said. "Our emphasis is on comets and the pristine material of the solar system." Yet missions to such bodies are more expensive than ESA can fund by itself so, of necessity, ESA's planetary program is collaborative. On the Cassini mission to Saturn and Titan, for example, ESA will build the Titan atmospheric entry probe, providing approximately 15 percent of the total project expenditure. In the Soviet Vesta mission to Mars and the asteroids ESA will work with the Soviet and French space agencies. For Caesar, a comet coma sample-return mission, ESA can afford only about half of the mission cost, so it is investigating possible *partners*.

"Our budget is both small and unpredictable," said Dr. I. Revah of the French space agency, CNES, "so we've limited ourselves for many years to instrumental participation with established space agencies." France recently flew instruments on the Intercosmos (the Soviet space agency) Vega missions to Venus and Comet Halley and will participate in NASA's Magellan mission to Venus. France will have five experiments on the Soviet Phobos mission to Mars to study the Martian atmosphere and will also participate in the NASA/ESA Cassini mission and the Intercosmos Vesta mission. "We are trying to get to a higher level of cooperation," said Revah, "we are trying to persuade our funding agencies of this."

Lou Allen, director of the Jet Propulsion Laboratory, spoke next on strategies for carrying out future planetary missions within NASA. "Following the Challenger accident NASA's first priority is to recover the Shuttle program." This has priority over everything else, so that launching a planetary mission on a Titan launcher appears as an additional cost to the agency. "The second priority is the Space Station," he noted, "and it's not doing too well."

"The third thing is space science, and within that NASA gives priority to astrophysics and Earth science," he said, qualifying this with, "or rather, planetary science is not faring well in that competition," since NASA does not formally set priorities between different branches of science.

But Allen brought out an interesting aspect of planetary funding. "Planetary launch windows increase the difficulty in getting new starts," he pointed out. The NASA bureaucracy seems to prefer missions that can be delayed, shuffled among available Shuttle launch dates, or put on hold for a few years — and planetary missions often can't be delayed. Planetary probes must be launched near certain dates if they are to reach their destinations. Earth orbiting observatories, on the other hand, can be launched at any time and thus are easier to program in the space agency's budget process and easier to launch on the Shuttle.

Allen also commented on the emergence of a new group within NASA and the science community, the Mars contingent. "This is a different group," Allen was careful to point out, "not the SSEC (Solar System Exploration Committee)." Urging cooperation between the United States and the Soviet Union, these people are pushing sample-return and manned missions to Mars and playing heavily on the political ramifications. "NASA has set the next ten months as the time it will decide its future course without prior constraints. There have been no decisions made yet."

David Morrison described the recent report of the Solar System Exploration Committee (SSEC) on two missions for an augmented budget — though the audience seemed amused at the very suggestion. One is a comet sample-return mission "with the sample returned in pristine condition," and the other a Mars Rover and sample return, "an intelligently selected sample," he emphasized. Morrison, a University of Hawaii astronomer, had also noticed the recent emphasis on manned missions to Mars and contrasted the Apollo-style approach to that of the SSEC: "Our objective is to lay out an absolutely exciting list of scientific questions and then answer them at a lower cost than previously possible."

"But we seem to be trying to do long-range planning in an environment which is uninterested in long-term plans and prefers an annual competition," said Morrison, with evident disgust in his voice, for it is hard to believe that NASA intends to anything to implement the long-term low-cost approach to planetary exploration the agency asked for and got from the SSEC.

I heard the same complaints again and again: NASA has a fixation with the Shuttle . . . the biggest justification for the Space Station is that it will employ lots of people . . . NASA only likes big budget items . . . the Shuttle's going to rob everything else's funding . . . certain administrators within NASA don't think space science is important . . . I tell my students not to go into planetary science. It's got no future.

Whatever their merit, a lot of planetary scientists seem to subscribe to these complaints. And that is very bad news at least in the short term. In the long term, as Joe Veverka put it, "history will remember our accomplishments in planetary exploration and will probably forget the machinations of the bureaucrats." I hope he's right.

Many of the papers presented on Thurday and Friday were similar to the papers presented at the Heidelberg comet conference. Harold Reitsma of Ball Aerospace showed a beautiful movie he *hadn't* shown in Heidelberg, made from Giotto flyby frames and showing the nucleus getting bigger and bigger, overflowing the frame, and ending with just the brightest jet. The whole sequence takes only thirty seconds or so. I hope that sooner or later every ASTRONOMY reader will have a chance to see it.

Then suddenly it was over. From October 27 until November 7, I'd been listening to papers, asking people questions, writing down ideas. . . . I realized by Friday I was totally exhausted. It had been an exciting two weeks, an excellent pair of meetings. An enormous number of papers was presented, and a lot of "science" got done. And as for that famous Comet Halley, its influence may be gone from the retail stores, but it's still alive and kicking in the world of science.

— *Richard Berry*

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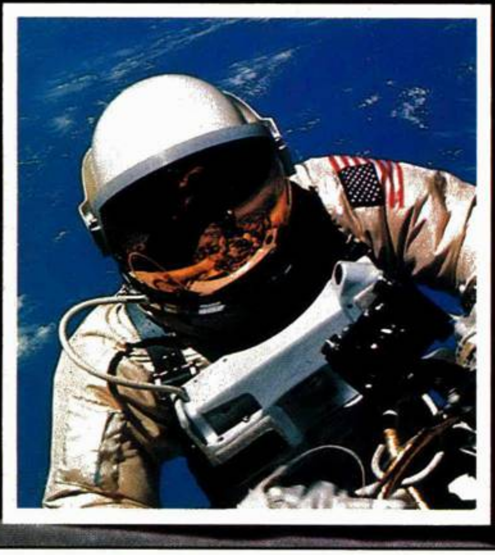

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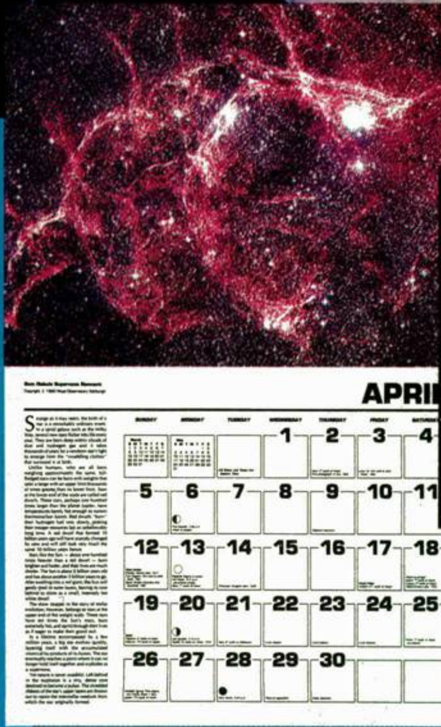

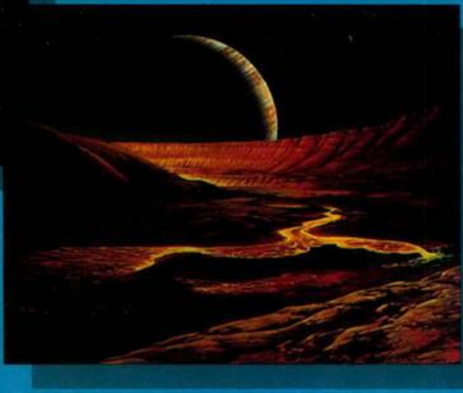

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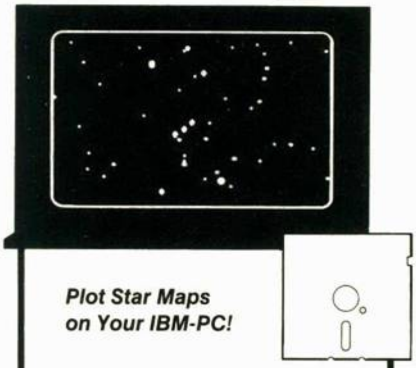

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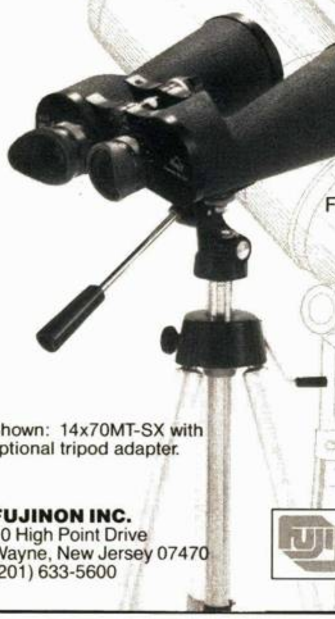

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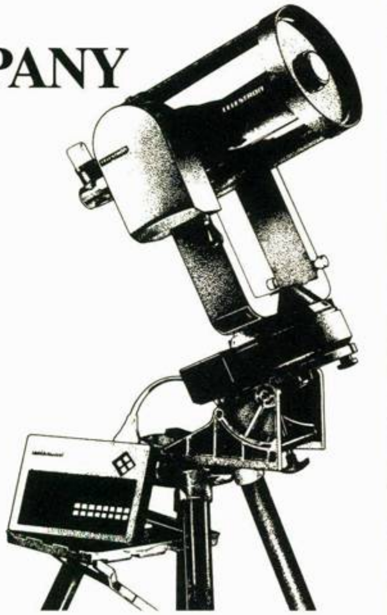

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ASTRONOMY

In Focus

Encourage Your Children

Sir / I've talked with parents who are afraid to buy their child or teen a telescope because the youngster could soon lose interest in astronomy and the instrument would end up in a corner gathering dust. While this happens occasionally, I think if the child shows some interest, then he or she should be encouraged.

How? Why not get him or her a good pair of binoculars. If there is more than curiosity after that first step, then graduate to more complex equipment.

Parents who see their children have an interest in astronomy should get some literature on the subject and read about the "heavenly wonders" with their children. You never know, Mom or Dad just might get bitten by the stargazing bug! Amateur astronomy can be a great family hobby.

Patrick J. Amaral
Hanford, CA

Following the Planets by Day

Sir / Early in December I enjoyed following Venus practically all day, ahead of the Sun. Finding and watching the planet move from east to west is a good pastime. It's fun looking for celestial objects — even in broad daylight.

Billie G. Butler
Bethany, MO

Sir / For several years I have enjoyed daytime views of Venus. With the aid of the Moon, which lay nearby, I have found the planet with binoculars, small telescopes, and even the unaided eye. I have often wondered, however, if Venus was the only planet that could be found this way.

About 3 p.m. on December 7, 1986, with the Sun still high in the southwest but blocked from view by my house, I located the waxing crescent Moon. After only a few minutes of searching I found my target — Jupiter — with 12x binoculars and with 7x binoculars, and then (barely) with the naked eye.

The following day I was again successful, although not until near sunset. I'm sure I was not the first to view Jupiter in the daytime, but I have never heard anyone report that he has seen Jupiter during the day.

Andrew S. Freiberg
Palo Alto, CA

—The secret of seeing Venus (or the other bright planets) during the day is knowing exactly where to look.

What's in a Name?

Sir / Walker Vaning's letter (In Focus, October 1986) claims the hypothetical solar companion cannot be called Nemesis because a planetoid has already been given that name. He also stated that the International Astronomical Union requires each body in solar orbit to have a different, unique name.

Historically, the IAU has not followed this rule, so either the Sun's companion star can be named Nemesis, or we will have to rename some of our well-loved moons.

I have included some examples of bodies with the same names: 9 Metis and the ninth Jovian moon, Metis; 38 Leda and the thirteenth Jovian moon, Leda; 106 Dione and the Saturnian moon, Dione.

Some of the bodies were named recently, long after their planetoidal counterparts were first given the same name.

Andreas Moehn
Wiesbaden, West Germany

— Brian Marsden of the International Astronomical Union says the main reason for duplicate names is that different committees name planetary satellites, asteroids, and other solar system objects. However, the IAU resolved at its 1985 meeting not to give asteroids the same names as planets or satellites in the future.

Underrated Binoculars

Sir / Ken Morris' "Binoculars for Astronomy" (Equipment Atlas, December 1986) was the best basic treatise I've seen for selecting binoculars for use in astronomy. However, Morris may have led some readers to underrate roof prism glasses because they were compared to Porro models. True, the roof prisms lack some light-gathering ability because of scattering, but a number of brands of roof prism glasses are good for astronomy.

I agree that a top quality 10x50 Porro prism with the latest lens coatings is probably the ultimate astronomical binoculars. The 8x36 models should also prove exceptional.

I tested a wide range of top-grade binoculars for a recent article in *Gun Week*, a publication for which I serve as roving editor. During my research I spoke with Mr. Morris and found him to be knowledgeable, eager to help, and enthusiastic. I'm not surprised his article was so comprehensive.

Jim Williamson
Dallas, TX

Great January Issue

Sir / I have been receiving your magazine for a year now, and I must say the January 1987 issue was the most beautiful and informative issue so far. The photographs, "Visit the Nearest Stars" by Ken Croswell, and the text of Riccardo Giacconi's speech in Forum were interesting and easy to understand.

Crystal Sarmiente
Tampa, FL

Enlightening Frustrated Astronomers

Sir / I have been an ASTRONOMY subscriber for the better part of the twentieth century, but I have two friends who need enlightening. Could you find it in your heart to send them complimentary copies of your magazine so we will have something important to discuss at our next annual condominium meeting in Maui, Hawaii, something other than condo maintenance fees, sexy Hawaiian girls, and why it doesn't rain once in a while?

Both of my friends are frustrated astronomers. Neither will ever become a Stephen Hawking or an Albert Einstein, but both deserve a chance to aspire.

I would like to send each of them an issue, except that that would leave a gap in my collection. There is an outside chance they may even sell some stock and take out a subscription. Anything is possible!

Meanwhile, I will continue to remain a staunch subscriber far into the twenty-first century or die trying.

Andy Andreiko
Solana Beach, CA

— You deserve the sample copies. We trust your friends will be enlightened.

Lunar Dome Catalog

Sir / A joint Association of Lunar and Planetary Observers and British Astronomical Association project to catalog lunar domes (hills) began in the late 1960s. However, the interest of observers waned after the magnificent success of the Lunar Orbiter and Apollo missions, and the project was never completed. Many of domes discovered as a result of the effort were never classified, cataloged, or published.

With the help of Dr. John Westfall, director of A.L.P.O., and Harry Jamieson, I have compiled a list of 594 domes using the old A.L.P.O. observation files. Less than two hundred of these discoveries were ever published.

Our initial goal is to classify and describe the domes and then publish a catalog. Observers interested in participating in this renewed Lunar Dome Survey Program will be assigned to confirm and characterize twenty to twenty-five domes from our list using telescopic observations and/or lunar charts and maps.

Anyone interested in helping with this project should contact me. A donation of stamps to help with mailing costs would be appreciated.

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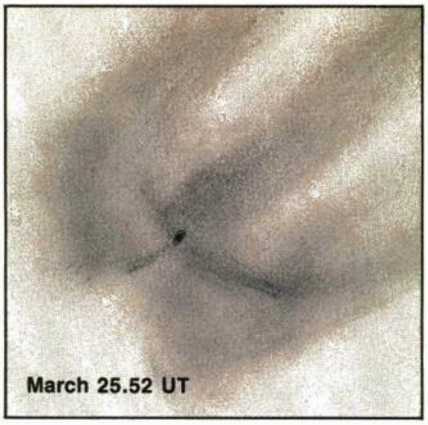
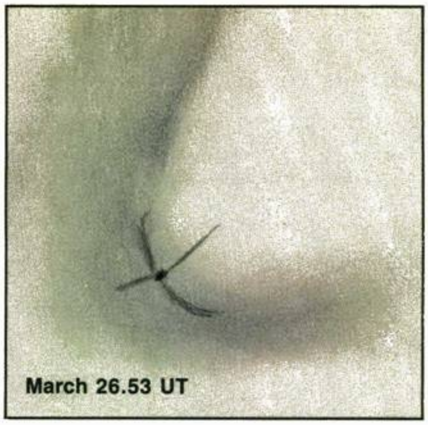


March 25.52 UT



March 26.53 UT

Oops!

In "The Eye's View of Comet Halley" by Charles S. Morris (Stellar Frontiers, January 1987), David Levy's drawing of Halley on March 25.52 UT was inadvertently replaced by his drawing made on the 26th. Both drawings are reproduced above.

Behind the Scenes

What's in Our Quarterlies

Besides ASTRONOMY, Kalmbach's eighth-floor editorial crew produces two magazines that offer their readers in-depth articles on building and using telescopes and on deep-sky observing, information that simply isn't available anywhere else. The magazines are *Telescope Making* and *Deep Sky*.

We've published *Deep Sky* for more than four years, and it's grown to forty pages. The Winter 1986 issue of *Deep Sky* features "Sailing aboard the Argo Navis," an eight-page article that describes dozens of deep-sky treasures in Carina, Vela, Puppis, and Pyxis. "Photographing the Northern Milky Way" is an eight-page photo essay of Robert Reeves' superb work. Reeve's photos have been shown in ASTRONOMY (see the December 1986 issue and this issue), but never as many as *Deep Sky* has shown its readers.

Deep Sky also features regular columns on double stars, variables, observing with small telescopes, the professional astronomical literature. David Eicher, an assistant editor for ASTRONOMY, is the editor of *Deep Sky*.

Telescope Making is now in its eighth year of publication and averages sixty-four pages per issue. The current issue, *TM#29*, has an exciting line-up of articles. "The Pretoria Eyepiece" describes the revolutionary new eyepiece design that corrects the optical errors of short-focus Newtonian reflectors by producing razor-sharp images to the edge of the field of view. In "A 14-Inch Ball-in-Socket Telescope," author Tom O'Brian tells how he built the unique sphere-mounted reflector that last year won a Merit Award at Astrofest.

TM#29 also features an Australian "flip-top" observatory that combines the convenience of a roll-off roof with some of the wind protection of the classic dome design. Dick Suiter's article on apodizing contains a powerful computer program that allows anyone to experiment with filters that supposedly improve telescope performance. *TM* often features in-depth reports on amateur meetings, and every issue has "Letters," and "The Blue Pages," with advertisements for telescope parts and components.

Subscriptions to *Telescope Making* and *Deep Sky* cost $12 per year. To order, use the form bound into each issue or phone (414) 272-2060 and ask for Customer Service.

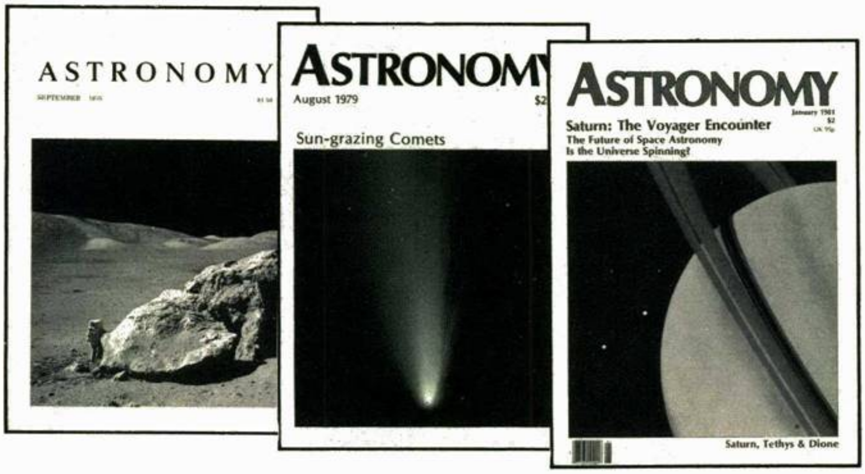
Now that you know what's in the current issues, we promise to keep you up to date on what's in each and every future issue of *Telescope Making* and *Deep Sky* as they are published.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

Guide to Back Issues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November 1975: Big Bang to Galaxy, Mars' New Frontiers, Find a Comet

December 1975: Astronomy from the Moon, The Planet Mercury, Stellar Beehive

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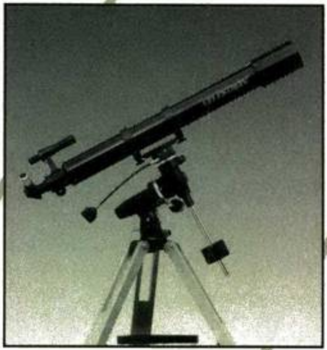

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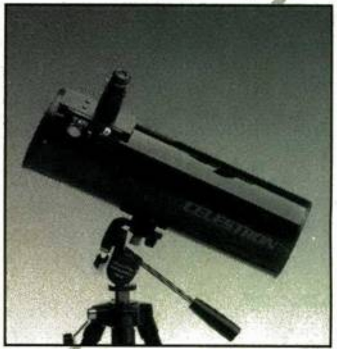

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ASTRONOMY
Reviews

Planetary Landscapes
Ronald Greeley
265 pages, cloth, $45
Allen & Unwin (1985)

Ronald Greeley seems to have personally explored much of the solar system. He is currently with the Department of Geology and the Center for Meteorite Studies at Arizona State University, and his biography states that for eleven years he worked on photographic interpretation of the Moon, Mars, and Mercury at NASA's Ames Research Center. He is also a member of the imaging science team for the Galileo Jupiter Orbiter/Probe and chairman of the NASA study project on Mars Evolution and Climatic History. With his background Greeley would seem uniquely suited to guide a tour of the solar system.

Indeed, Greeley seems exceptionally good at choosing photographs. *Planetary Landscapes* opens with a remarkable series of photographs of Mars showing the unprecedented way that resolution has improved in the last twenty years. The series begins with an Earth-based telescopic image of an apparently featureless blob, which we are told is the giant volcano Olympus Mons, and continues with a Mariner-7 photograph from an altitude of 495,086 kilometers and from approximately the same angle and scale as the first photograph. Again, Olympus Mons can be seen, but it doesn't appear like a volcano. An overlay on this second photo shows the location of photo three — a Mariner-9 image of the Kasei region from 2,835 kilometers away. Photo four is a Viking image of the same area and shows an apparently smooth volcanic plain. Photo five, at about three times the resolution, shows us that the area is cratered. In photo six we see what appear to be individual lava flows. Photo seven is centered on the Viking-1 landing site over one of those flows. The final photograph is a familiar image of the surface, and in this photograph we can compare the craters visible on the horizon with those seen from orbit in photo seven. This series, with essentially no text, shows us exactly where the Viking-1 landing site is in relation to geographical features on the planet's surface.

The heavy emphasis on photographs brings home many aspects of planetary science and exploration that are usually treated only in print. In the first chapters alone we *see* laboratory simulations showing how size-frequency distributions can be used to age a cratered surface, how an artificial impact re-distributes materials on a planetary surface, and how artifacts in a spacecraft camera or communication system can show apparent features that are not real. The usefulness of image processing to bring out different kinds of details is again demonstrated with photographs.

The majority of the book is about our own Moon. As Apollo samples and data continue to be studied, lunar volcanism appears to be gaining acceptance. Scientists seem certain they have found volcanic craters and even shield volcanoes. Lava flows dominate the lunar mare and are even discernible in the ancient battered highlands. Rilles seem to be accepted as lava tubes, and "topographic benches" on mare shores are interpreted as "high lava marks," which were left before the lava retreated to the present surface. Mare ridges, however, are no longer interpreted as the edges of lava flows but rather as the result of faulting and/or volcanism within the cooling lava flow on which they are superimposed.

The lunar chapter concludes with a brief "History of the Moon," which suggests that recent evidence indicates "lunar volcanism may have extended to relatively recent times (post two billion years).

"Although [they] have 5,000 times better resolution than Earth-based telescopic views, it is important to keep in mind that most Mariner-10 images of Mercury are comparable to Earth-based telescopic views of the Moon," says Greeley. Although the lack of contrast between "highland" and "smooth plains" makes Mercury appear more heavily cratered than the Moon, less of Mercury's surface is actually saturated with craters. This suggests that the planet may have been more volcanically active than the Moon.

Although "volcanism is repeatedly called upon to explain various features observed on Mercury and is inferred to have occurred throughout its history . . . very few features such as domes, cones, and shield volcanoes, can be unequivocally identified as [being] volcanic." But that is probably because of the relatively poor resolution of Mercurian photographs.

The only chapter not dominated by photographs is the one on Venus. Earth-based radar maps and a single high-resolution image from Venera-15 show probable volcanoes and tectonic structures. Why is it that so few images from the Soviet radar mapping missions to Venus have appeared in the West? Greeley offers no clues, but I assume if he had had access to them, he would have used them.

On Mars the existence of volcanoes is beyond question. When we think of Martian volcanoes, we usually think of giant shields of the Tharsis ridge. But one of the most spectacular planetary photographs I've seen is of Hecates Tholus in Elysium, an old, battered, but vast shield fairly covered with channels, possibly carved by flowing rivers of lava. Another summit caldera is filled with lava, from which flows appear to cascade into a much larger impact crater nearby.

A class of structures unique to Mars so far are the variously termed "splosh" craters, ejecta-flow craters, or rampart craters. Of them Greeley says, "It has been suggested that [ground] water or the atmosphere of Mars, or both, may have been responsible for the form of the ejecta." A spectacular photograph shows where ground-hugging ejecta from a fifty-kilometer crater splashed around, but not over a smaller, nearby crater.

Planetary Landscapes has a curious

makeup: about two-thirds of it is photographs. The text is little more than an overview, yet at the same time it is quite technical, and probably too technical for the casual reader.

Nonetheless, I recommend the book as an atlas of the landscapes of the star system in which we live, which is exactly what it was intended to be. *Donald F. Robertson.*

From Quark to Quasar
Peter Cadogan
183 pages, cloth, $24.95
Cambridge University Press (1985)

Few of us have not contemplated the vast, unlimited reaches of the universe. Does it have an edge? If so, what lies beyond? Similarly we wonder about that mysterious world beyond the microscope's limits.

If we can imagine the largest, most distant object, couldn't there be something just slightly larger and more remote? And if the smallest extant entity could be isolated and quantified, perhaps it is possible to halve it and produce something even smaller.

For ages mankind has been fascinated and intrigued by the macrocosm and the microcosm. And while much of this is the stuff of dreamers and philosophers, everything in between is within the realm of science. Thus, a survey of the scale of the universe, linking everyday, recognizable objects to those observable only with the most powerful telescopes and microscopes, has a ready audience. *From Quark to Quasar* aims at this inquisitive group.

The opening chapter of this well-illustrated volume is an introduction describing various types of distance scales and their use, especially those which are not commonly used in everyday life. Commencing with a basic unit — one meter — the author ties our human size of approximately two meters to a number of familiar like-sized objects: ocean waves and meteorites, among others.

A tenfold increase in size is the basis for the next sequence, or "frame," as Cadogan calls it. At this stage we are confronted with houses, buses, large machines, and similar ten-meter objects. Like the preceding frame, the following one is again a tenfold increase in size. Like its predecessor this frame is a combination of text and excellently-reproduced color photographs.

And so it goes. This logarithmic progression continues throughout the book. Astronomical objects and distances are quickly reached.

Frames seven through thirteen, for instance, encompass Earthlike worlds, giant planets, satellite systems, giant stars, and the inner and outer solar system.

We soon arrive at frame seventeen, one that depicts objects and distances on a ten light-year scale. At this stage the reader is presented with several photographs of nebulae and star clusters having dimensions of ten light-years. The accompanying text describes neighboring stars in addition to objects directly related to the ten light-year scale, or a multiple of this frame's basic unit. The progression continues until we arrive in the vicinity of the most remote objects known — the realm of quasars.

In approximately one hundred pages Cadogan transports his audience from the comfortable, meter-sized objects of everyday outward to the enigmatic quasars. Then, in the final frame, after a cursory glance at quasars, the book returns us to frame one where we are prepared for a journey into the microcosm, taking tenfold decrements in decreasing size. As we delve deeper into the very small, microphotographs rapidly yield to electron micrography as increasingly smaller scales are explored.

Finally, frame twenty-one takes us beyond quarks into the theoretical world of rishons and antirishons, hypothetical particles of which quarks may be composed. The journey to the infinitesimal is easily as interesting as the earlier leaps outward into the cosmos.

The final chapter of the book is a rambling but mostly coherent overview of

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the two voyages along the size-continuum of the universe. The author briefly considers extremes related to things other than size: temperature, density, and energy. He momentarily ponders the anthropic principle, whereby the existence of life is the determinant that effectively selects our own particular universe out of all possible universes.

Lavish with color, non-technical in language, and appealing in the sense that the almost-knowable is attractive, *From Quark to Quasar* is good reading for a cloudy night. And for those moments when your mind and imagination could use a shot of stimulation, this book will fill the bill. *Gail O. Clark.*

To Utopia and Back

Norman H. Horowitz
192 pages, paper, no price given
W. H. Freeman (1986)

Utopia is imaginatively defined as a fanciful and indefinitely remote locale, a place of ideal perfection. But this description does not accurately fit *Utopia Planitia*, the landing site of the Mars Viking Lander 2. This "utopia" is a desolate rocky region of the Red Planet from which an astonishing amount of data was transmitted to Earth in the mid-1970s.

Does life exist on Mars, or any place other than Earth? This question has been asked so many times and there is such a flood of literature on the subject that it's hard to address intelligently. This is the problem faced by writers of books on this complex and speculative subject.

Fortunately, *To Utopia and Back: The Search for Life in the Solar System* is typical of literature about extraterrestrial life: it has a message, is largely well-written, and is authored by an expert.

Norman Horowitz, former head of the Jet Propulsion Laboratory's bioscience section for the Mariner and Viking Mars probes, is a much-published author who writes with clarity and simplicity. The basic fault with his book is not its content, but that it contains no new message.

The first third of the book deals primarily with biology, explaining specifically what life is and speculating about where it might have originated. With the assumption that extraterrestrial life would be based on the chemistry of carbon, as ours is, he explains why the probability of extraterrestrial life in the solar system is small.

Horowitz next examines three theories on the origin of life: spontaneous generation, panspermia (the idea that life somehow traveled to Earth from elsewhere in the cosmos), and chemical evolution. The last theory is shown to be the most likely. With the stage set, Horowitz explains the criteria necessary for an environment suitable for chemically evolved, carbon-based lifeforms.

First, temperature and pressure must be within certain limits. In addition, a suitable atmosphere and a solvent (like water) is required. Sound reasons are given: lifeforms meeting other necessary criteria simply could not exist in an environment with temperatures in excess of 250 degrees Celsius because nucleic acids, fundamental to life, break down at this temperature.

It takes only a short time and few words to eliminate airless solar system bodies such as the Moon, other satellites, and the asteroids as possible biosystems. Similarly Mercury, Venus, Jupiter, Saturn, and the outer planets are all found lacking conditions necessary for life. The search for a biologically acceptable place for life in the solar system leads, not surprisingly, to Mars.

Between 1963 and 1969 Mars was found to be an apparently lifeless, Moon-like world, not the place of tranquil life and beauty created by Percival Lowell. But the 1976 Viking missions changed the face of Mars forever.

The final three chapters of the book analyze the findings of the Viking probes, comparing Martian and terrestrial characteristics and examining the water requirements of Earthly flora and fauna. Lichens, bromeliads, kangaroo rats, insects, and micro-organisms that are able to exist in a desert environment are examined as candidates able to survive the rigors of the Martian surface. Horowitz uses the Viking results as *prima facie* evidence against the possibility of life on Mars.

Included in the book are eight color plates, mostly standard shots of the Orion Nebula, Saturn, and Jupiter, as well as a couple of familiar photos of Mars. They add little to the book aside from increased price, being unconnected to the text in any significant manner.

There are no surprises in the book. And for those who have kept reasonably current on Martian exploration, there is little to recommend it. *Gail O. Clark.*

Origin of the Moon

W. K. Hartmann, R. J. Phillips,
G. J. Taylor, eds.
781 pages, cloth, $25
Lunar & Planetary Institute (1986)
[publisher's address: 3303 NASA Road 1, Houston, TX 77058]

As co-editor and planetary scientist William Hartmann candidly admits, discovering the origin of the Moon was one of those motherhood-apple pie issues that helped get the Apollo project going. But the lunar origin question wasn't simply a load of hooey thrown together to bamboozle the politicos. In fact, most planetary scientists thought the question would be settled easily — perhaps as soon as they opened the first lunar rock box.

Well, it didn't turn out to be quite so simple. And the question of the origin of the Moon illustrates perfectly what happens in science when the data are too scant to support the theorizing.

Indeed, no seriously worked-out model for the lunar origin appeared before 1879, when George Darwin (son of the famed naturalist) proposed that the Moon was born from a piece of the Earth. This proto-Moon was flung off when tidal instabilities, reinforced by the Sun's pull, first raised and then tore out a large piece of the rapidly-spinning early Earth. A little later, another scientist peered at the terrestrial globe and pointed to the Pacific Ocean as the scar that was left.

With modification, Darwin's melodramatic fission hypothesis withstood scrutiny until the 1930s, when Harold Jeffreys, an English geophysicist, raised several irrefutable objections on dynamical grounds. With the fission idea set aside, an older idea was then dusted off and re-examined: the Moon coalesced from the same solar material as Earth had.

This binary-planet or "coaccretion" model was especially attractive since it didn't presuppose any events or processes unique to Earth — and scientists are habitually leery of ad hoc explanations that depend on these. This model had difficulty, however, explaining why the Moon turned out to be made of much lighter material than the Earth was, a fact brought out by dynamical studies.

A third model became popular in the 1960s — capture. In this concept, the Moon, thought to be a primitive and undifferentiated object, was formed somewhere else in the solar system and, when it passed close to Earth, was caught by Earth's gravitation. Unfortunately this model depended heavily on some very complex celestial mechanics, along with its other defects. For anyone predisposed to doubt the theory, these mechanics smacked far too much of arm-waving wizardry.

By the time the Apollo moonships were poised to go in the late 1960s, these three theories stood in uneasy rivalry — all had certain successful aspects and all had serious drawbacks. The problem was that no one knew enough facts about the Moon to discriminate between these theories.

When the scientists examined the first lunar samples, they must have thought: "This ain't gonna be as easy as we figured . . ." The problem was that the samples, even those from a "simple" mare site like Tranquillity Base, were far more complex and had undergone much more processing than anyone had dreamed the ol' dead Moon could cook up.

When no quick and easy answer emerged, the question was quietly dropped. Faced with a flood of complex and messy data, any good scientist puts the big questions on hold and explores the smaller pieces that lie at hand. Gradually, as the histories of enough individual rocks were worked out, a picture of the geological past of each landing site began to emerge, and these pictures in turn led to regional syntheses. Weaving together the regional stories finally established a large body of hard fact that any global theory would have to account for.

This process took about a decade. By the early 1980s, therefore, a feeling began to take shape in the community of planetary scientists that it was time to reopen the question of where the Moon came from. "It appeared to us that by announcing a major topical conference specifically devoted to the problem of lunar origin," Hartmann said, " we might encourage new thinking from leading data analysts as well as planetary theorists." The conference, held at Kona, Hawaii, in October 1984, was highly successful. It was also the first lunar-origin conference to be held in twenty years.

This book reprints the papers given at the conference. It contains thirty-three papers gathered into eight sections. The first four sections cover the history of the origin problem as well as dynamical, geochemical, and geophysical constraints on theories. The last four critically examine theories of origin that depend on fission, capture, coaccretion, and a large impact on Earth.

Although post-Apollo work has given scattered support to the older theories, an entirely new origin theory that looks pretty good has emerged. Its details are fuzzy, but it says that you can make a Moon very much like the one we now have if a Mars-size planetesimal slams into the early Earth late in its accretion stage. This would knock off part of the crust and mantle and eject iron-poor and volatile-depleted material into orbit around Earth, where some of it would coalesce to form the Moon. Depending on when the impact happened and how differentiated the Earth was by the time of impact, the theory seems to neatly account for the compositional differences between the Earth and Moon.

At the moment, this new "collision-ejection" model stands as the most popular — though its success as a theory may have more to do with a lack of adequate tests than with any inherent quality. For example, many scientists appear to choose it simply because they like the older theories even less. All the same, Hartmann notes that while organizing the conference he saw many papers arrive that had independently converged on this model. He thinks that, in general outline at least, the collision-ejection model will last.

Is that, then, where the Moon came from? Probably, more or less.

But we will never know just how it happened until we return to the Moon for more samples and more fieldwork.

Although I've long been interested in the Moon, I have to confess I'm not a scientist and therefore large parts of this book were opaque to me; I can't critique the intricacies of dating rocks by ratios of iridium, plutonium, and xenon isotopes, for example. On the other hand, I did follow the two history-of-models chapters and I found the summaries in most papers largely comprehensible.

Would I buy the book? I think I *will* get my own copy if only because this has to be the best book bargain of the year: 780 pages, typeset, hardcover, sewn binding — all for $25! On the other hand, if you are only casually interested in the Moon, you can safely skip this work and plan to get a Moon book once the exciting new ideas from this conference have had time to percolate into the popular works. For my part, however, I know I'll be dipping back into the papers from time to time to refresh and extend my understanding of lunar origins. *Robert Burnham.*

Solar Neutrinos and
Neutrino Astronomy
M. L. Cherry, W. A. Fowler,
and K. Lande, eds.
322 pages, cloth, $44.25
American Institute of Physics (1985)

Containing the proceedings from the 126th AIP conference on research into solar neutrinos and neutrino astronomy, this volume deals with topics as broad as the "Chlorine Solar Neutrino Experiment" and "Neutrinos from Stellar Collapse."

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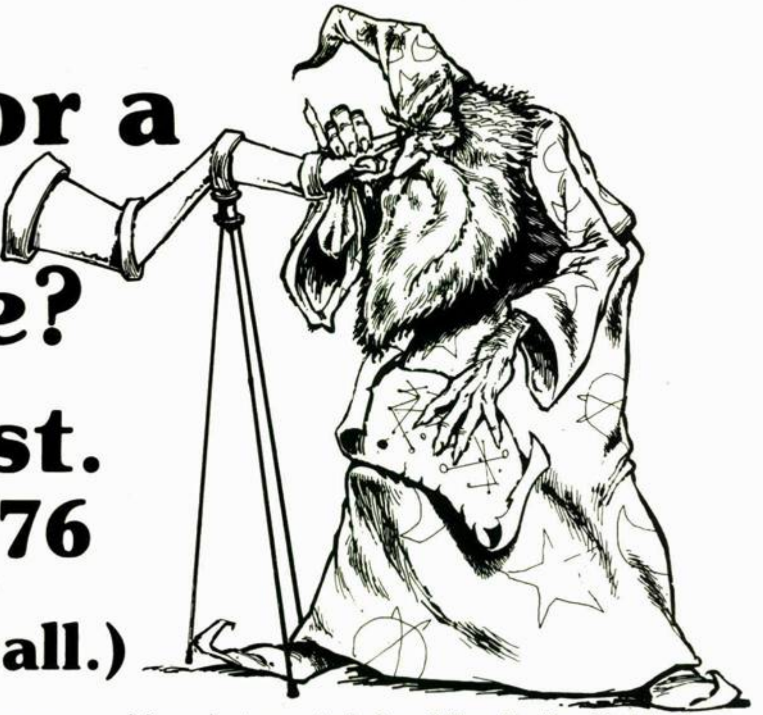

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Touring the Stellar Cycle

Gazer's Gazette

by Edmund Fortier

R Monocerotis is located at the southern tip of Hubble's Variable Nebula, embedded in the dust and gas from which it is forming. When the nebula is brightest, however, its glow can drown out the light of the star. Photo by Bill Gordon.

Although stars are still forming from the dust and gas in the Orion Nebula, many stars have already been created. Ernest Wright took this photo showing the brightest stars of the incipient cluster in the central region of the Great Nebula. Most prominent is Theta^1 Orionis, the quadruple-star system better known as the Trapezium.

The next night you have a dark and transparent sky, set up a medium-sized telescope, insert a low-power eyepiece, and aim it about halfway between the bright stars S and 13 Monocerotis. You should find a small, rather faint triangular patch of light. If you then move the telescope 13° north in declination and a touch over an hour west in right ascension, you'll come to an oval glow that is larger than the triangular patch and more than a magnitude brighter. Except for its triangular appearance, little distinguishes the nature of the first smudge of light from the second, and you might casually assume they belong to the same family of deep-sky objects.

In fact, the objects you have just observed — NGC-2261 and M-1 — are not celestial cousins at all; rather, they represent two vastly different stages in the lifetime of a star. NGC-2261, also known as Hubble's Variable Nebula, is a fan-shaped cloud of dust surrounding the stellar embryo R Monocerotis. Embedded in the brighter southern tip of the cloud, R Monocerotis fluctuates irregularly between magnitudes 11 and 13 and is the source of the nebula's variability. But, while NGC-2261 is a stellar birthplace, M-1, the Crab Nebula, is a stellar graveyard: the remains of a star torn apart by a violent supernova explosion.

Between the dusty birth of a star and the convulsive outburst of a supernova lies the whole cycle of stellar evolution — a grand panorama in which a star's behavior or a cluster's appearance is linked to its niche in the evolutionary scheme. Why not set aside an evening soon to examine this cycle more closely? Besides taking you places you might not otherwise go, an orderly tour of the night sky will give you new perspectives on each of the stops along the way. All you need is a 4- to 6-inch telescope, a dark sky, and a willingness to brave the frosty nights.

With R Monocerotis as an appropriate beginning, let's continue our tour with a look at the youngest stars we can actually see — the nebular variables. No longer stellar embryos like R Monocerotis, these fledgling stars are emerging from the dust and gas that concealed the earliest stages of their formation. The prototypical nebular variable is T Tauri, which is located less than 2° northwest of 3rd-magnitude Epsilon (ε) Tauri and fluctuates erratically between magnitudes 8.4 and 13.5. Depending on its inherent variability and your skill at detecting small changes in brightness, you may see T Tauri flicker several times in one evening or stay unchanged for weeks.

If T Tauri proves too elusive a target, try looking at AB Aurigae. This star is the brightest example of a nebular variable and is plotted in both the *Atlas of the Heavens* and *Sky Atlas 2000.0*. Situated 2.5° south of 2nd-magnitude Iota (ι) Aurigae, AB Aurigae fluctuates between magnitudes 6.9 and 8.4. These spasms of stellar birth eventually cease when the star settles down to a long and stable life, as all nebular variables must.

So far we have looked only at individual stars. However, stars form as members of clusters and associations from vast clouds of dust and gas. The nebular variables, for example, are nearly always associated with incipient groups, and R Monocerotis

One of the more impressive objects in a low-power eyepiece is the Double Cluster in Perseus, which is made up of two very young clusters containing dozens of supergiant stars. Despite their extreme youth, a few of the cluster members have evolved into red supergiants that are visible both in small telescopes and on this photo by Sheldon Faworski.

Somewhat older than the Double Cluster but still young by astronomical standards, the Christmas Tree Cluster in Monoceros contains many hot, massive stars, as well as a number of nebular variables that have yet to reach the main sequence. The faint nebulosity evident in Jack Newton's photo, particularly the Cone Nebula at the southern tip of the "tree" (which appears upside-down here), is extremely difficult to detect in the eyepiece.

The open cluster M-37 in Auriga is substantiall older than the Pleiades and shows clear signs being further evolved. There are no extremel hot, massive main-sequence stars in M-37 typic of young clusters, and there are a dozen or s stars that have evolved to the red giant stage Photo by Walter Hamler.

is an outlying member of the young cluster NGC-2264. Such stellar aggregates form continuously in the Galaxy, and by observing them in order of increasing age you can witness the results of 5 billion years of cluster evolution in a single evening. To get your best views of these extended objects, use a low-power, wide-angle eyepiece.

The youngest open clusters are visually dazzling: they are typically compressed, wreathed in bright and dark nebulosity, and contain many brilliant O- and B-type suns. A fine example of such a stellar nursery is M-42, the Great Nebula in Orion, which can easily be found in the middle of Orion's sword. This glowing complex of dust and gas is illuminated by the light of the centrally located multiple-star system Theta^1 (θ^1) Orionis and, very probably, Theta^2 (θ^2) Orionis, which lies just 135″ to the southeast. Theta^1, better known as the Trapezium, is a beautiful quadruple-star system, which may have begun shining just 20,000 years ago. Together with the surrounding stars, many of them faint irregular variables, it constitutes the center of a dense cluster still forming in the nebula's interior.

Now return to the vicinity of Hubble's Variable Nebula. About a degree northeast of that object you'll find NGC-2264, a coarse stellar grouping 20′ across sometimes called the Christmas Tree Cluster because of its distinctive shape. With an age of about 20 million years, this cluster is nearly one thousand times as old as the Trapezium, though it is still young by astronomical standards. Outshining the other members is magnitude 4.6 S Monocerotis, an optical double with an extremely luminous brighter component that may not yet have reached the main sequence. Following S Monocerotis, the cluster's two dozen or so brightest stars range from magnitudes 7 to 9 and most show spectra characteristic of hot, massive, O- and B-type stars. The area is rich in nebulosity, especially in the southern region surrounding the Cone Nebula, a dark nebula very difficult to detect visually.

Compare NGC-2264 with a slightly older cluster 35° to the south, NGC-2362 in Canis Major. Its brightest star, Tau (τ) Canis Majoris, is a 4.4-magnitude object that makes this group easy to find. NGC-2362 is intrinsically compact, and with about sixty stars spanning 8′ — about one-third the diameter of NGC-2264 — it appears much richer. Surprisingly, this cluster lacks any trace of nebulosity and Tau, its centerpiece, is not a brilliant young star but a slightly evolved giant.

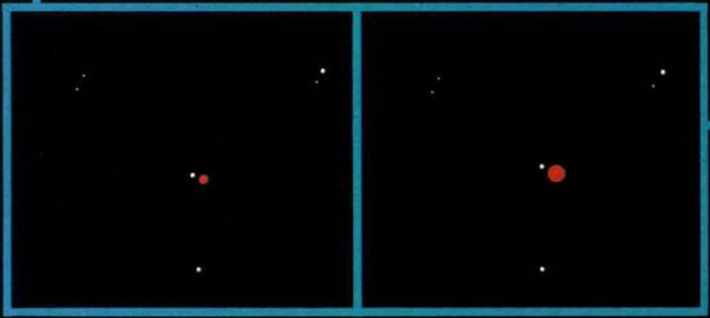
As a cluster ages, residual dust and gas are swept away by strong stellar winds and the brightest, most massive stars evolve into red giants. The clusters of the Double Cluster in Perseus, NGC-869 and NGC-884, are respectively 5.6 million and 3.2 million years old. Despite their youth these clusters contain no nebulosity, and their most massive members have evolved off the main sequence. Take a careful look at NGC-884 and you may detect the ruddy tint of several red giants.

Many of the naked-eye stars of the Pleiades cluster (M-45), with an age of just 78 million years, have evolved off the main sequence. Material ejected from these rapidly rotating suns envelops them

The Pleiades are a transitional open cluster: old enough that many of its brighter stars have evolved off the main sequence, yet young enough to have substantial nebulosity. Photo by Robert Provin and Brad Wallis.

Although most open clusters contain some stars that have evolved off the main sequence, such stars are easiest to see when they're not overwhelmed by other cluster members. The rarest and brightest of these evolved stars are the bright supergiants, and the constellation Orion, seen in this Stephen Walther photo, has several outstanding examples. Betelgeuse, forming Orion's east shoulder, is a red supergiant, and Rigel and Epsilon Orionis, the Hunter's west knee and the middle star of his belt respectively, are blue supergiants.

Most of the bright members of M-67, the second oldest open cluster on our tour, are yellow, orange, and red giant stars. Photo by David Ratledge.



Even farther along the evolutionary scale are the periodic variable stars. The classic long-period variable Mira is shown here at minimum brightness (left), when it is 9th or 10th magnitude and invisible without a telescope, and at maximum brightness (right), when it is 3rd magnitude and an easy naked-eye target.

in a reflection nebula, brightest around Merope. This is a transitional group: it's old enough to have periodic variable stars and still young enough to retain conspicuous nebulosity. Older yet, at 190 million years, is M-41 in Canis Major. Its bright central star is a red giant, and a careful observer will find a few others scattered among the blue giants.

To further scale the evolutionary ladder, aim your telescope at M-37 in Auriga (300 million years old), one of the finer sights in the winter sky. Near the cluster's center look for a 9.2-magnitude red giant, the most vivid of the dozen or so such stars belonging to this group. The 660-million-year-old M-44 in Cancer is one of the clusters closest to us and therefore appears brighter but sparser than most of the others. Its fifty members span over 1½° and shine at a combined magnitude of 3.1. Of its fifteen brightest stars, four are orange giants.

Turn next to the intermediate cluster NGC-7789 in Cassiopeia. This visually impressive cluster contains three hundred stars packed into a 16′ angular diameter and shines at magnitude 6.7. Although the cluster is 1.6 billion years old, some five hundred times older than NGC-884 in Perseus, it still doesn't rank as one of the two oldest clusters on our tour. That distinction belongs to our next two stops.

First search about 9° south of M-44 and you'll find M-67, a 7th-magnitude collection of over two hundred stars spanning 10′. Of the sixty or seventy suns you are likely to see, most are giant stars shining with hues of red, orange, and yellow.

The oldest of the open clusters on our tour — NGC-188 in Cepheus — lies just 4° from Polaris. Most of its 120 members are faint stars, so the cluster as a whole appears as a luminous haze at low powers. The few stars bright enough to be seen individually are yellow giants. In visual appearance NGC-188 is a magnitude fainter and only half the angular diameter of M-67.

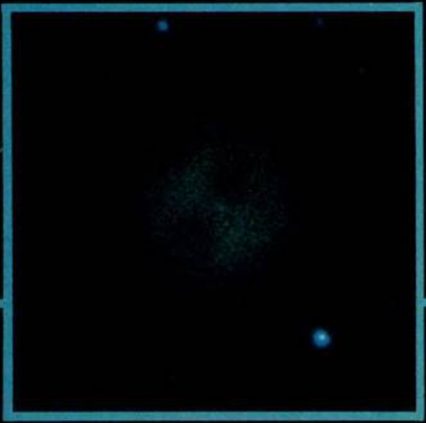
Not long ago M-67 and NGC-188 were thought to be 10 billion and 11 billion to 14 billion years old respectively, but more recent estimates place their ages closer to 3.2 billion and 5 billion years. If you want to view an even older stellar group, you'll have to turn from the galactic disk to the galactic halo and seek out a different kind of cluster.

Lepus, the constellation immediately south of Orion, contains the winter sky's only bright globular cluster, M-79. Located nearly 4° south and about 4′ west of Beta (β) Leporis and shining at magnitude 8.0, this compact cluster can be resolved at the outer edges with a 6-inch telescope at high power. Globular clusters have ages exceeding 10 billion years, which makes them the most ancient of all stellar aggregations.

Unlike M-67 and NGC-188, most open clusters are found along the spiral arms of the Milky Way where they are ultimately dispersed by the shearing effects of galactic rotation. We turn to the resulting field stars to continue our tour of the stellar cycle.

Having noted a number of anonymous giants among the open clusters, we shall look now at some familiar ones. Beta (β) Canis Majoris is the prototype of slightly evolved blue giants, while Rigel (Beta [β]

The most massive stars cannot end their lives by forming planetary nebulae and then settling down as white dwarfs. Instead these massive stars undergo cataclysmic explosions, called supernovae, that result in chaotically expanding nebulosity. The best example of such a supernova remnant is the Crab Nebula in Taurus. Although it is faintly visible with a 4-inch telescope, a large telescope or photograph is needed to see the filamentary structure. Photo by Bill Iburg.



During the final stages of its life, a star may throw off the outer layers of its atmosphere to form a planetary nebula. The Owl Nebula is one of the better examples of this class of objects, although a telescope of modest size and excellent observing conditions are needed to get a good view. Photo by Jack Newton.

Once a planetary nebula has dispersed, all that remains of the original star is a corpse of extraordinary density known as a white dwarf. Omicron^2 Eridani is a triple-star system containing the only white dwarf easily accessible with a small telescope. Joseph Kaznica's photo of Omicron^2 Eridani shows a main-sequence primary orbited by a companion star resolved into two components: a blue-tinged white dwarf and a red dwarf.

Orionis), Betelgeuse (Alpha [α] Orionis), and Epsilon (ε) Orionis belong to the rarest and most luminous of all stellar classes — the supergiants. Because these stars are extremely short-lived, they are found primarily in young clusters and associations such as the Double Cluster and the Orion complex.

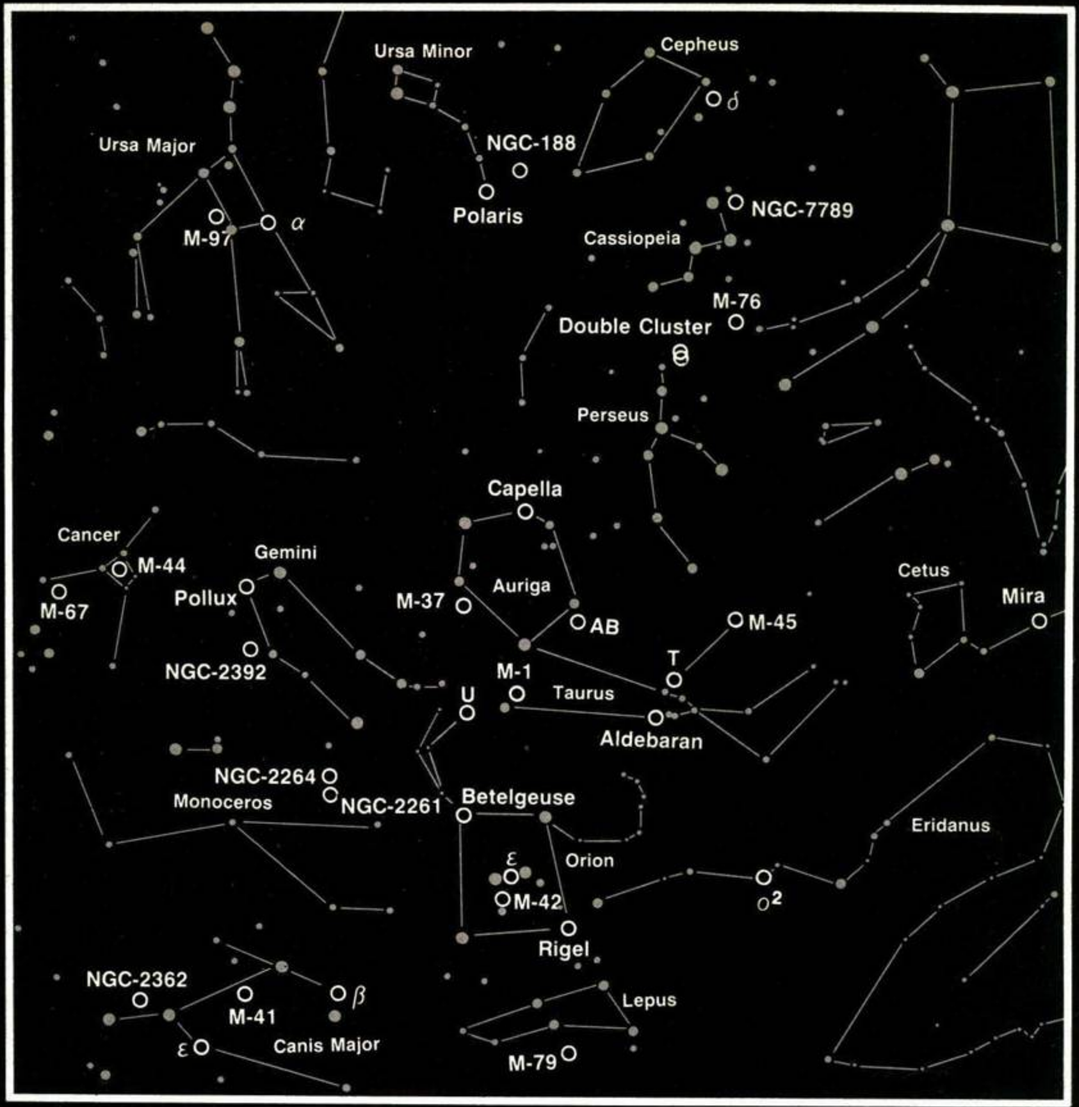
More numerous than the supergiants are the bright giants — stars such as Epsilon (ε) Canis Majoris and Alpha (α) Ursae Majoris. (Can you distinguish the red one from the blue?) The giants themselves, represented most prominently in the winter sky by Capella (Alpha [α] Aurigae), Pollux (Beta [β] Geminorum), and Aldebaran (Alpha [α] Tauri), are the most common type and account for the majority of bright stars in older clusters like NGC-7789.

Just as young stars fluctuate erratically as they struggle toward maturity, aging giants — responding to very different internal forces — are also characterized by variability. Those we have looked at so far are only slightly variable. However, at a certain point in their evolution, supergiants begin to pulsate with astonishing regularity. Their brightness varies by up to a magnitude over a period of a few days. The prototype of these short-period variables is Delta (δ) Cephei, which fades from magnitude 3.5 to 4.4 and then brightens again every 5.4 days. The most prominent Cepheid variable, however, is Polaris (Alpha [α] Ursae Minoris). It has a period of 4 days and a 0.15-magnitude range that requires careful monitoring to be detected visually.

Still farther along the evolutionary line are the giants associated with the galactic halo: the Mira and RR Lyrae (or cluster) variables. None of the RR Lyrae stars, which typically have periods of about 1 day, is brighter than 7th magnitude, but several Mira variables reach naked-eye visibility at maximum brightness. Mira itself (Omicron [ο] Ceti) reaches about 3rd magnitude at its brightest, drops slowly to 10th magnitude, and then returns over a semi-regular period averaging 332 days. Fainter than Mira but still conveniently bright is U Orionis. Located in the northern part of Orion, its magnitude ranges from 4.8 to 12.6 and back again with a period of about 372 days. Such long periods allow even a casual observer to follow the slow pulsations of these cool and ancient giants.

Ultimately, all stars must die. Most die quietly, leaving behind a tenuous shell of expanding gas called a planetary nebula. One of the better-known planetaries visible this time of year is M-97, the Owl Nebula in Ursa Major. Located just 2° southeast of Beta (β) Ursae Majoris, M-97 presents a large and relatively featureless disk that glows with an integrated magnitude of 12.0 — you'll need a dark sky for a good view. Compare M-97 with NGC-2392, the Eskimo Nebula in Gemini, which lies 2.5° southeast of Delta (δ) Geminorum. Much smaller and 2 magnitudes brighter than M-97, this planetary is easy to find. It has a distinct bluish cast and 10th-magnitude central star.

Last, try to find M-76 in Perseus, often considered the most difficult object on Messier's famous list. Situated a degree north and a little west of Phi (ϕ) Persei, M-76 has an elongated, irregular shape



A tour of the stellar cycle can offer new perspectives on the night sky, and there is no better time to start than on a clear winter's night. The thirty-three objects on this map cover the range of stellar evolution from nebular variables to supernova remnants.

quite unlike that of the other two. With the exception of the one in NGC-2392, the central stars of these planetaries are very dim, and none has yet reached full-fledged white dwarf status. To view one of those stellar corpses, you must look elsewhere.

Half a degree north and 15° west of Rigel, in the constellation Eridanus, is an unpretentious triple star. Designated Omicron^2 (o^2) Eridani, it consists of a 4.4-magnitude orange primary star and a close 9.5- and 11.2-magnitude pair 83″ away in position angle 104° (1970). Compare the hues of the two fainter stars. The dimmer one, perceptibly ruddy, is a red dwarf and one of the least massive stars known. In contrast, the other shines blue-white. This is Omicron^2 Eridani B, one of the nearest and brightest of all white dwarfs. It is about twice the diameter of Earth but contains half the Sun's mass, which results in an average density more than 15,000 times that of lead. Omicron^2 B is probably the easiest white dwarf to observe — far easier than its more famous cousin, Sirius B.

Finally, let us return to M-1 in Taurus. Massive stars like the one that produced the Crab Nebula do not die quietly: they end their lives in stellar catastrophes called supernovae explosions. When M-1 first blazed forth in 1054 A.D., it probably rivaled Venus in brilliance. The pale 8.4-magnitude glow you see in the eyepiece now is the chaotic aftermath of the explosion, which is still expanding outward at tremendous velocities. At its center lies a tiny but massive neutron star, which is too faint to be seen visually. White dwarfs like Omicron^2 Eridani B may be among the oldest objects we can see, but supernova remnants — at least those of the Type II variety such as M-1 — mark the deaths of massive stars that have lived only a short time, their life cycles accelerated by their own incredible masses.

Cycles repeat. The shock front of the Crab supernova may one day disturb a distant cloud of interstellar dust and gas and trigger its collapse around local condensations of matter. Eventually, an embryonic star embedded in one of those dusty cocoons will become dense enough to ignite hydrogen fusion. Still contracting gravitationally and fluctuating erratically as it adjusts to its new status as a star, it may resemble R Monocerotis shrouded in the dust and gas of Hubble's Variable Nebula. Thus the cataclysmic death of the Crab Nebula's progenitor may precipitate the birth of a new star, and the cycle will continue.

A tour of the stellar cycle can trace only a single strand of a wonderfully intricate pattern. But there are many tours you can take, each with its own itinerary and special attractions and all offering new views of a scheme so vast and remote that, from our perspective, the scheme is forever fixed in the heavens. Such tours provide a way of unraveling the complex pattern of stellar evolution, of imposing — at least temporarily — a semblance of order on an overwhelming universe.

Edmund Fortier is a high-school teacher living in North Scituate, Massachusetts. His last article for ASTRONOMY, "The Lost Stars of James South," appeared in the October 1985 issue.

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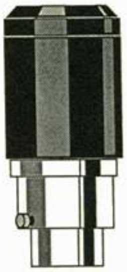

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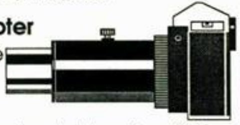

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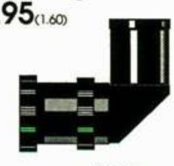

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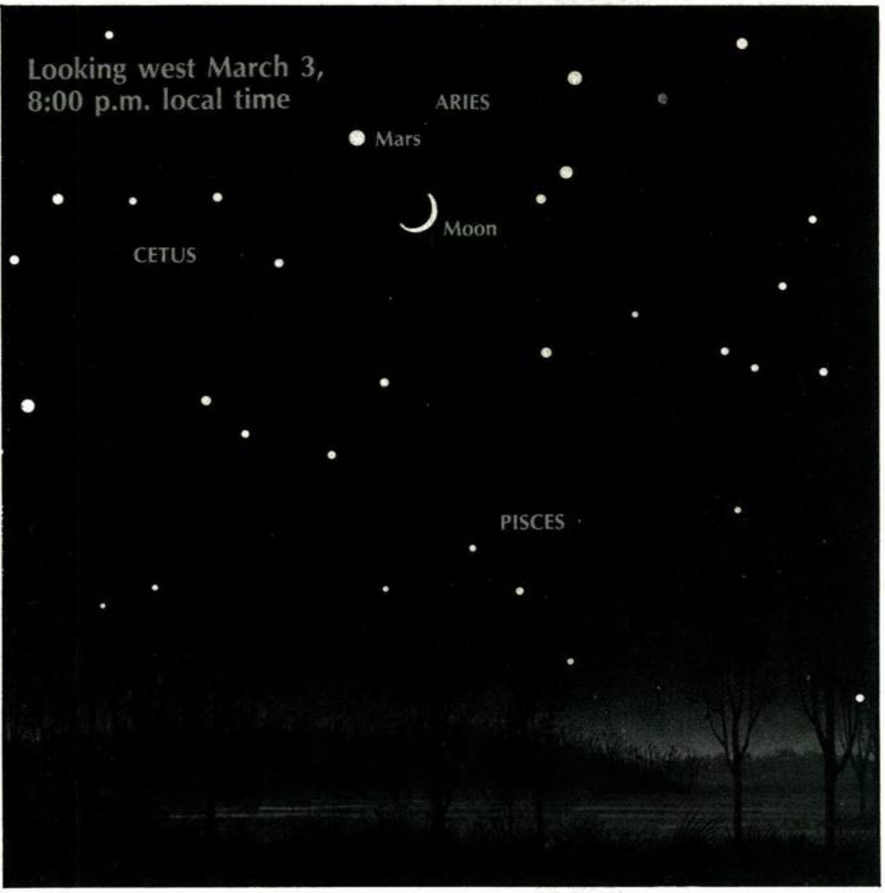
Eye on the Sky

The Sun Overtakes Jupiter

by Robert Burnham



The Wanderers

During the past few months the Sun has been catching up to the planets of the evening sky one by one. This month it's **Jupiter's** turn. On March 1 and for several days thereafter you can still see the planet low in the west soon after sunset. Jupiter is a bright (magnitude −2.0) white object about as far above the horizon as the width of your palm held at arm's length (approximately 10°). Jupiter's stellar backdrop is the constellation Pisces, which the Sun is approaching as it nears the vernal equinox on March 20. Slower-moving Jupiter, therefore, is about to vanish into the nimbus of light surrounding the Sun.

How far into March you can follow Jupiter depends in part on local viewing conditions. Obviously, a clear sky is necessary, but so is a flat horizon free of trees, houses, and hills. In any case, Jupiter will be gone from sight by about March 5. On the 27th, it finally passes behind the Sun and will reappear in the eastern sky before sunrise sometime in mid-April.

With Jupiter gone, the only naked-eye planet in the evening is **Mars**. Located in Aries, Mars is easy to find because it is the brightest object in an otherwise dull region of sky. After sunset look for Mars in the west-southwest less than halfway between the horizon and overhead. Its amber-colored light has a brightness of magnitude 1.4. (If you can spot the little star cluster called the Pleiades, you'll find Mars is the bright object 15° below it and slightly to the right.)

To see the rest of the planets, set your alarm clock early and plan to be outside an hour before sunrise. The stars you'll see are those of an evening in July, so in a sense you're getting a preview of summer. (Just for fun, haul out last July's Star Dome chart and re-learn those summer constellations.) The brightest "star" visible in the dawn is the planet **Venus**, only about 10° above the southeastern horizon. Two months ago Venus was much higher, but it has been slowly dropping ever since. Venus is easily recognized by its brilliant white gleam; its brightness (magnitude −4.0) is unmatched by any other planet.

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.

Mercury is always elusive and this month's apparition is more difficult to follow than most. Mercury is visible to the lower left of Venus from about the 11th to the 29th, but there's a catch: it has less than *half* of Venus' elevation and at magnitude 0.5, it is almost one hundred times (five magnitudes) dimmer!

Mercury is at its highest elevation above the horizon from the 19th to the 21st, yet it is so low you will have to look for it as twilight grows stronger by the minute. Station yourself somewhere with a flat eastern and southeastern horizon and look for a 1st-magnitude ocher-hued dot of light very low in the sky. Use binoculars if you have them.

The last of the five naked-eye planets is **Saturn** and, unlike Mercury, Saturn is quite easy to locate. In the chill predawn skies of March two constellations straddle the meridian in the south: Scorpius to the west and Sagittarius to the east. Ivory-white Saturn, shining at magnitude 0.4, lies about halfway between and slightly higher than these constellations. The only nearby star you could mistake for Saturn is Antares in Scorpius. But Antares, amber in color, lies to the lower right of Saturn and is perceptibly dimmer.

The constellation Orion is framed in the opening of an observatory dome housing a 24-inch Cassegrain telescope. Photo by Peter Alway, who used Ektachrome 400 film and a 16mm, f/2.8 fisheye lens.

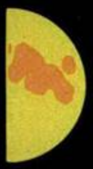
The Starry Sky

Two of the sky's best-known constellations are prominently visible during late March evenings. The first is **Ursa Major** the Great Bear, popularly known as the Big Dipper. If you face north, you'll see it upside down high above Polaris the Pole Star. (Not sure which star is Polaris? Extend a line northward through the two pointer stars of the Dipper, marked Alpha [α] and Beta [β] on the Star Dome, until you reach a star as bright as they are.)

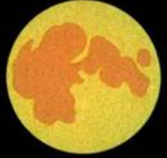
Polaris stands at the tip of the Little Bear's tail. Known officially as **Ursa Minor**, this group is also called the Little Dipper. Composed of stars generally fainter than those of its big brother, the dipper shape is hard to trace completely when viewed from light-polluted locations, although Kochab (β) and Pherkad (γ) are usually clear enough.

While the Great Bear is so high in the sky, try to identify all the stars marked on the map. The seven in the Dipper (eight,

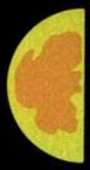
March Night Sky



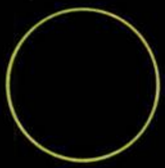
First Quarter
March 7
6:58 a.m. EST



Full Moon
March 15
8:13 a.m. EST



Last Quarter
March 22
11:22 a.m. EST



New Moon
March 29
7:46 a.m. EST

1st The thin crescent Moon lies very close to Jupiter this evening; it will occult the planet for viewers in parts of South America, Africa, the Arabian peninsula, and southwestern Asia.

7th First Quarter Moon occurs at 6:58 a.m. EST. This is probably the last day you can spot Jupiter low in the western sky after sunset.

9th The Moon is farthest from Earth at 5:30 a.m. EST: 251,517 miles (404,766 kilometers).

15th Full Moon is at 8:13 a.m. EST.

19th From today until the 21st, Mercury is at peak elevation in the morning sky, though this is a poor apparition.

20th The Sun crosses the celestial equator (heading north) at 10:52 p.m. EST. This marks the vernal equinox and the start of spring in the Northern Hemisphere.

21st The bright star Antares (Alpha [α] Scorpii) is occulted by the Moon for viewers in Africa and Madagascar.

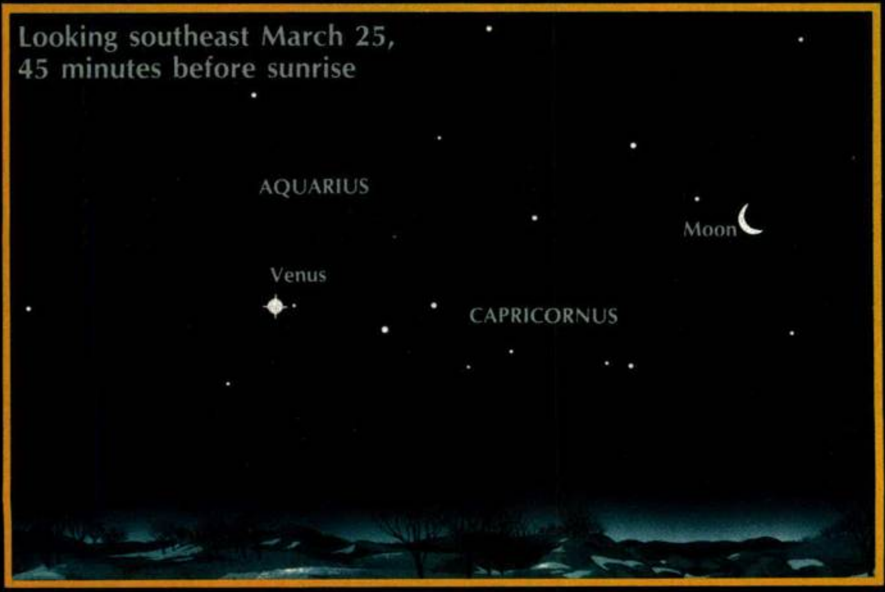
22nd Last Quarter Moon occurs at 11:22 a.m. EST.

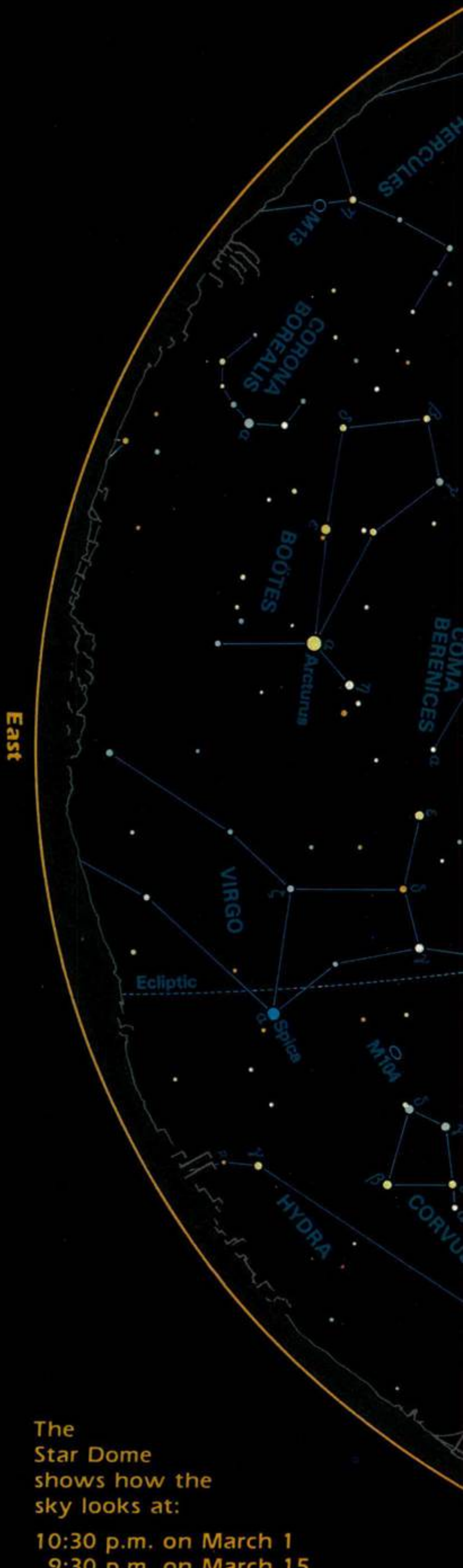
24th The Moon is closest to Earth at 2:04 p.m. EST: 229,272 miles (368,967 kilometers).

26th Mercury is at greatest western elongation in the morning sky.

27th Jupiter is in conjunction with the Sun and shifts into the morning sky.

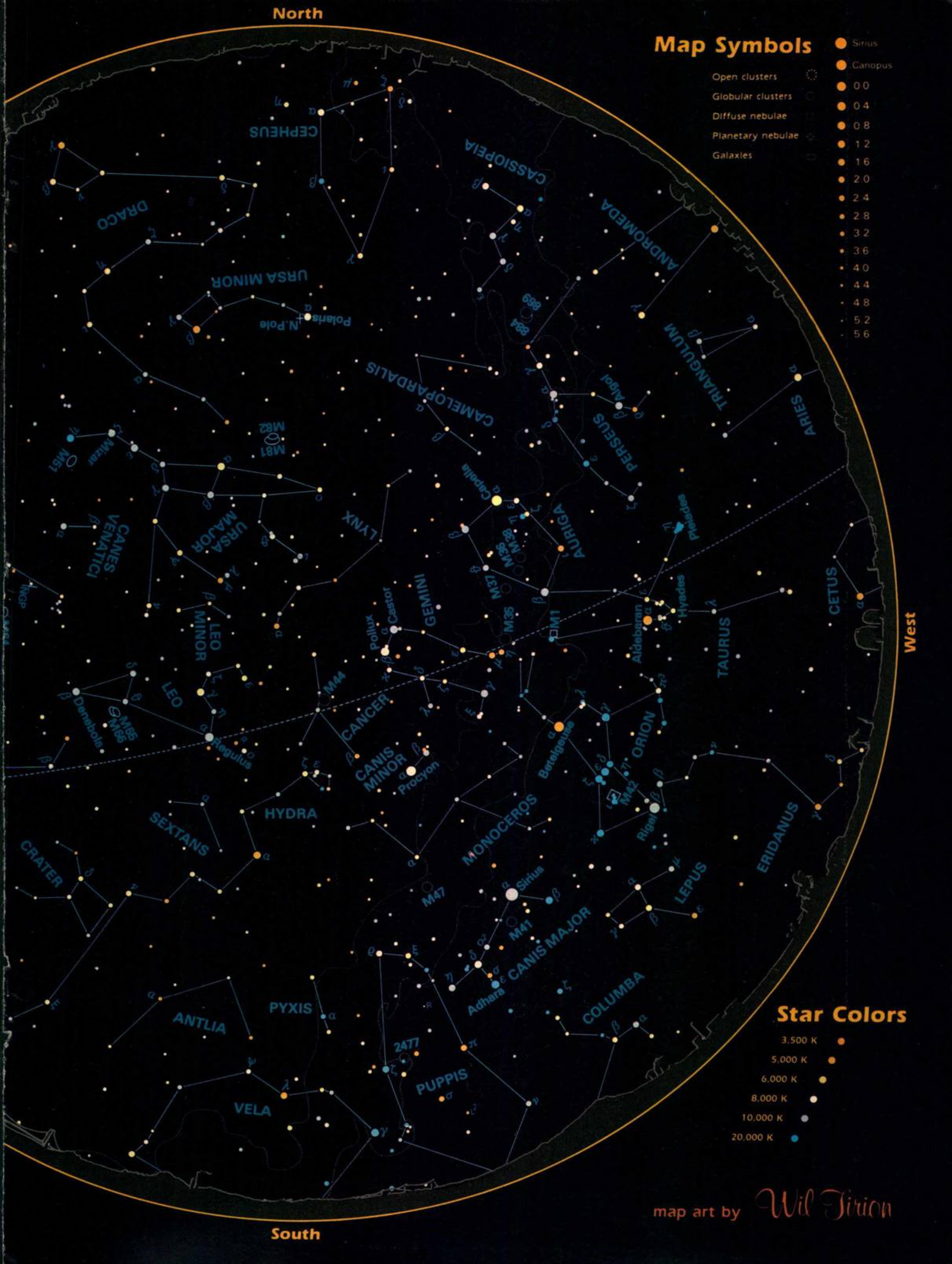
29th The Moon is New at 7:46 a.m. EST. An annular-total solar eclipse will be visible from southern South America and across central Africa.


Looking southeast March 25,
45 minutes before sunrise
AQUARIUS
Moon
Venus
CAPRICORNUS


HERCULES
M13
CORONA BOREALIS
BOÖTES
COMA BERENICES
Arcturus
East
VIRGO
Ecliptic
Spica
M104
HYDRA
CORVU

The
Star Dome
shows how the
sky looks at:

10:30 p.m. on March 1
9:30 p.m. on March 15
8:30 p.m. on March 31


North
Map Symbols
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies
Sirius
Canopus
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
4.0
4.4
4.8
5.2
5.6
CEPHEUS
CASSIOPEIA
DRACO
ANDROMEDA
URSA MINOR
Polaris
N.Pole
869
884
TRIANGULUM
CAMELOPARDALIS
Algol
ARIES
PERSEUS
M82
M81
Mizar
M51
Capella
Pleiades
LYNX
URSA MAJOR
CANES VENATICI
AURIGA
M38
M36
M37
CETUS
M35
M1
Hyades
GEMINI
Castor
Pollux
LEO MINOR
Aldebaran
TAURUS
West
M44
CANCER
Denebola
M65
M66
LEO
Regulus
Betelgeuse
ORION
CANIS MINOR
Procyon
M42
Rigel
HYDRA
SEXTANS
MONOCEROS
ERIDANUS
CRATER
LEPUS
M47
Sirius
M41
CANIS MAJOR
Adhara
COLUMBA
ANTLIA
PYXIS
2477
PUPPIS
VELA
South
Star Colors
3,500 K
5,000 K
6,000 K
8,000 K
10,000 K
20,000 K

map art by Wil Tirion

if you include little Alcor next to Mizar in the bend of the handle) are easy, but what about the Bear's other parts? The nose isn't too hard to find, but most people lose track of the legs somewhere in Leo Minor and Lynx.

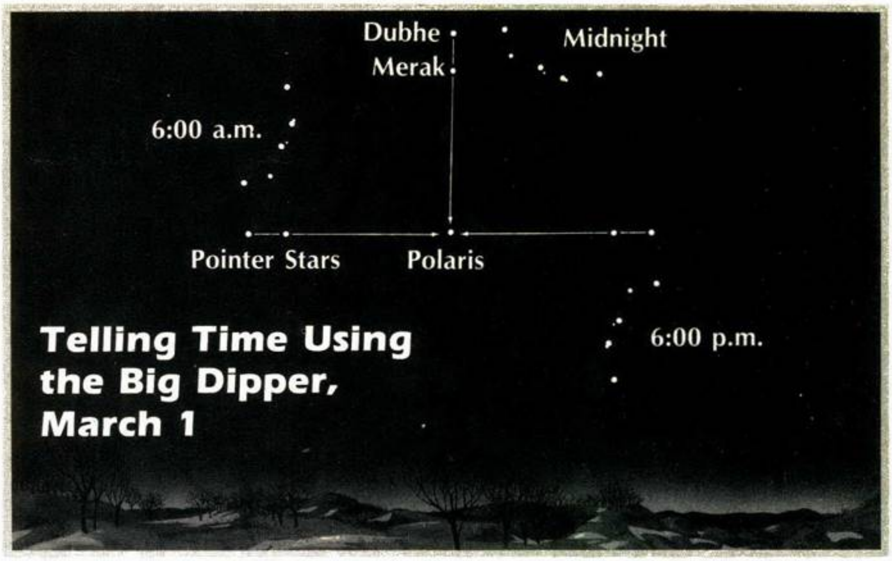
Wrapped around the bowl of the Little Dipper is **Draco** the Dragon. Its α-star, called Thuban, was once the pole star and will be so again by the year 23,000 A.D. as precession slowly alters where the Earth's axis points in space. Draco's head may be lost in horizon haze in the early evening, but at later hours (or at this time of night in a month or two) it will be visible.

The Great Bear's tail forms an arc that leads to a 1st-magnitude star hanging over the trees in the east. The star is Arcturus, main luminary of **Bootes** the Herdsman. The constellation Bootes has a shape that reminds many of a kite, an ice cream cone, or (turned around) a "belly-warmer" necktie. If you extend the arc-to-Arcturus farther from Bootes, you "speed on to Spica," the brightest star in **Virgo** the Maiden. Spica represents an ear of wheat in the Maiden's hand, and in antiquity the entire figure represented the goddess of grain and plenty.

Above Arcturus and tucked in beside the Dipper lie Berenice's Hair, **Coma Berenices**, and the Hunting Dogs, **Canes Venatici**. Neither group is prominent, although under a dark sky a large loose star cluster in Coma is visible to the naked eye (and is also easy in binoculars). Many galaxies reside in Coma and Virgo, but these lie deep in "telescope territory."

The Great Bear's nose points westward over the pole to an eye-catching yellow star named Capella, which belongs to **Auriga** the Charioteer. Most people see a pentagon in Auriga's shape, but one of his stars actually belongs to **Taurus** the Bull, which is why the map shows two βs in the figure. Capella means "little goat," and just to Capella's lower left (as you face northwest) lie three 3rd-magnitude stars called the Kids: Epsilon (ε), Eta (η), and Zeta (ζ).

The Taurus-star poking Auriga is named Elnath, which is Arabic for "the butting one" — a highly suitable name! However, most of Taurus' stars lie in the bright open cluster called the Hyades: the V-shape of the Hyades indicates the bull's face. (Aldebaran, a foreground star not a part of the cluster, is his angry eye.) The lovely daughters of Atlas and Pleione, collectively called the Pleiades, stand northwest of the bull's head as if to distance themselves from the snorting animal.



Telling Time Using the Big Dipper, March 1

Besides the well-known Dipper, tonight's other celestial landmark is **Orion** the Hunter. If you face Taurus, Orion lies just to the left of the Bull, and his three Belt stars are instantly identifiable. Standing above Orion is the constellation **Gemini** the Twins, marked by the bright stars Castor and Pollux. Above Gemini scuttles the dim figure of **Cancer** the Crab. If your sky is very dark, look for M-44, an open cluster easily visible to the naked eye. (Binoculars make it even easier.) About halfway between Gemini and Spica over in the east, bright Regulus marks the forepaws of the crouching Lion, **Leo**.

Although we haven't described a large dim region in the southeast, it is populated by a huge figure whose shape we can discern better next month.

Skylore

Long before people had mechanical clocks to tell them what time it was, they used sundials to mark the daylight hours. But nighttime was a different matter. Although a few "moondials" existed, they were difficult to use because of the complicated motions of the Moon. Instead, the ordinary person's night clock was Ursa Major. The Dipper is still as easy to use tonight as it was in centuries past.

Along with the rest of the stars in the sky, the Dipper makes one circuit of the Pole Star in twenty-four hours. (It actually circles once in twenty-four hours minus about four minutes.) Thus, if you look northward several times during the night, the Dipper appears to make a slow counterclockwise circle around Polaris.

Since one complete circuit (360°) takes twenty-four hours, the Dipper moves through a 90° arc every six hours. For example, as the sky darkens into night on March 1, a glance northward shows the Dipper standing on its handle, with the pointer stars lying directly to the right of the Pole Star. At midnight on the same date, the Dipper's bowl lies above Polaris with the pointers pointing straight down. Six hours later still, as dawn brightens the sky, your last glimpse of the Dipper shows it poised on the lip of the bowl directly to the left of the Pole Star. During the twelve-hour March night the Dipper makes a 180° arc.

Now as the weeks pass and March becomes April and then May, June, and so on, the Dipper's location at nightfall changes. This is due in part to the ever changing time of sunset, but it also happens because that four-minutes-per-day shortage adds up. The result is that for every passing month at the same time of night (ignoring Daylight Savings Time) the Dipper is farther along on its circuit by a distance equal to two hours' rotation. For example, at midnight on March 1 we saw the Dipper's pointer stars lying above the pole, but at midnight on June 1 they will lie directly to the left of the pole. (Three months times two hours each equals six hours, or a 90° change.)

Continuing on, at midnight on September 1, the pointers will lie straight below Polaris. By December 1, the midnight Dipper will be climbing up on the right hand side of the pole again, and by March 1 next year, the Dipper will be back to the position you see it in tonight.

For nightly timekeeping, then, spring is the best season of the year to learn to use this "shepherd's clock," because the Dipper's arc is high above the pole during all the hours of darkness. (Autumn, on the other hand, is the worst time, because the whole arc lies below Polaris, where trees, hills, and haze clutter the view.)

With surprisingly little effort, however, you can learn to tell the time within an hour, provided you know the season and can get a clear look at Ursa Major. In doing so, you'll be adopting skylore from the ancient past and making it your own.

Top left: Greg Mort took this photo of the partially eclipsed Sun projected on a maple leaf during the October 3, 1986, annular eclipse. The image was formed by a hole in a nearby leaf and photographed using Kodachrome 64 film and a 1/60-second exposure.

Bottom left: The Moon edges away from the Sun's disk in this photo taken near the end of the July 20, 1982, eclipse. J. Trayhern used ISO 100 film, a 600mm lens at f/8, and a 1/250-second exposure.

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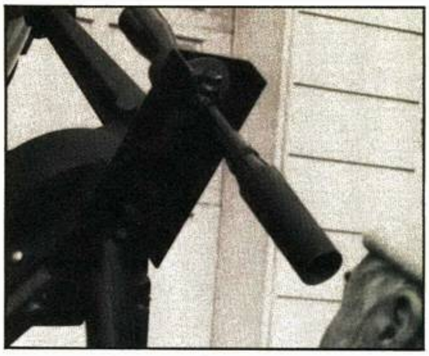

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Equipment Atlas

Gearing Up for Summer Deep-Sky Observing

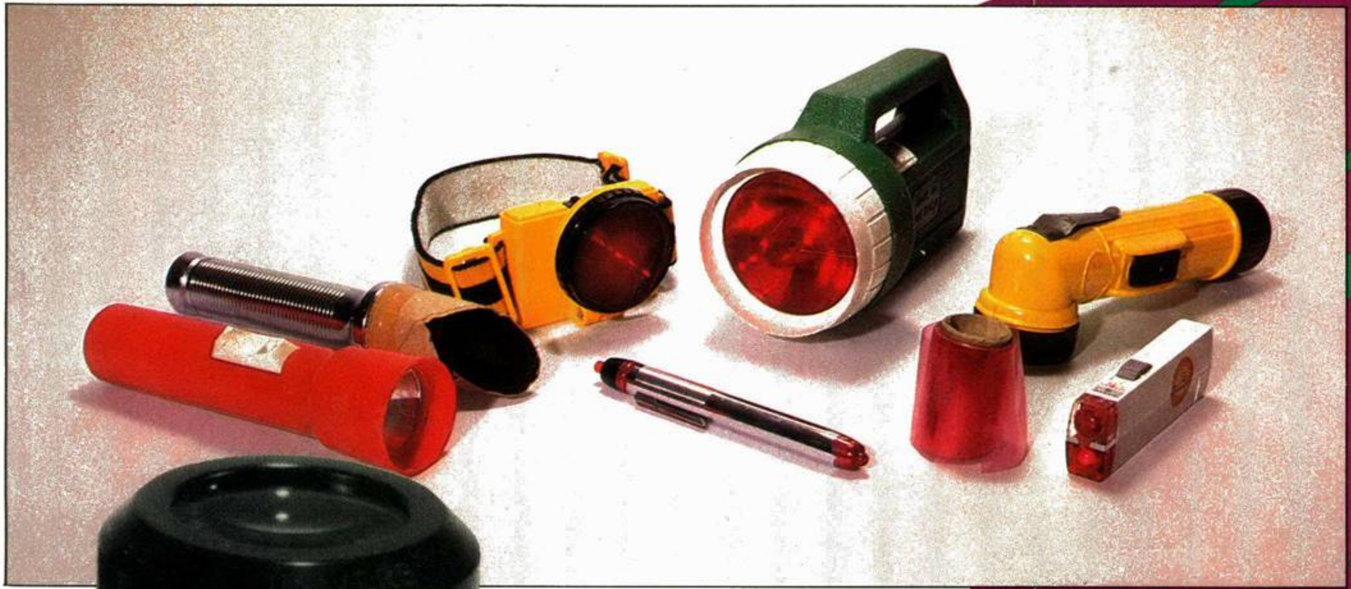
Don't look now, but it's about to happen again. Each and every spring a little bell rings in their heads. Deep-sky observers in northern climes rouse themselves from a self-induced, near-hypnotic trance, struck by the notion that summer will be upon them before too long. It's what is known as the spark of the warm weather observing season, which signals the time to get out those moldy observing lists, dust off the star atlases, drool over the latest eyepiece catalogs, and dream about the warm, satisfying views of the Lagoon Nebula to come.

The motto of the deep-sky observer can be summed up in a single sentence: "Arrive with everything you need — always." Too often a potentially good observing session is ruined by the discovery that, after driving fifty long miles to your favorite dark-sky site, you've forgotten to bring that vital Allen wrench. Because the modern deep-sky observer needs so many accessories — a drive corrector, eyepieces, an observing stool, flashlights, warm clothes, pencils, tools, and paper, to name just a few — making a checklist of the materials you need to take observing is wise and will help ensure happy times under the stars this coming summer.

Overdress for Success

Before thinking about what you need for your telescope, think about yourself. The most important consideration for personal comfort during observing is wearing enough warm clothes. Observing is an activity involving little exercise. Instead of actively generating heat, you simply stand around moving star charts and telescope parts. Under the crisp, clear sky you radiate heat away as fast as possible into the air. Because of this, "overdressing" is important, even during the summer. Depending on your observing location, a 78° F daytime temperature, for example, can drop to a cool 45° at night, and after three hours that's bone-chilling cold if you're standing around in a T-shirt.

The best preparation for late night observing during any season is dressing as if you're going skiing. Start with long underwear, warm socks, a comfortable shirt, heavy pants, and boots. Then add another layer, including a warm sweater — preferably a turtleneck — a light jacket, warm gloves or mittens, and headgear of some sort. (Covering your head is particularly important because most of the heat leaving your body escapes through your head.) Layering clothes in this fashion will give you insulating air pockets that will help keep you as warm as possible for long periods of time. Remember, once you're outside in the field observing, you



Astronomical flashlights come in all shapes and sizes. The silver-barrelled model (second from left) is fitted with a 45°-hood to shield glare from your eyes while its paper filter provides a soft glow for reading maps. A medical penlight (front center) can be clipped inside a pocket when it isn't needed. Panasonic's ''miner's lamp'' (third from left) frees hands and lights up a path wherever your head points. Sanyo's Cadnica light (right) is compact and uses two lamps: one can be painted dark red and the other light red. All photos in this article by Art Schmidt.

The most important accessory for deep-sky observing is an eyepiece that makes you happy. Many makes and models exist both in 1¼'' and 2'' barrel diameters; the best way to choose between eyepieces is by using some at a star party and finding out which ones you like best. Other accessories include nebula filters (left front) and Barlow lenses — also in 1¼'' and 2'' barrel diameters (left rear). A collimating eyepiece (right front) saves a great deal of time when aligning the optics in a reflecting telescope.

Which Star Atlas Is Best for You?

March's Night Sky
Map Symbols
Star Colors

ASTRONOMY's center spread star map shows you stars and bright deep-sky objects in the evening sky throughout the year. But what if you want a more detailed atlas for finding hundreds of faint objects? This comparative bibliography should help you decide which star atlas is best suited for you.

Each of the many popular star atlases in print today has its own distinctive features. This sampling will help you decide which particular atlas or atlases will best aid you in finding deep-sky objects.

Beginner's Star Atlases

Collins Guide to Stars and Planets, Ian Ridpath. 384 pages, William Collins Sons & Co., 1984. The *Collins Guide* offers twenty-six all-sky charts showing the naked-eye sky for different times of year at different latitudes. It features a series of eighty-eight constellation maps measuring 3¾" by 5¾", which show about three thousand stars down to magnitude 5.5 and a small number of deep-sky objects. The coordinates used are epoch 2000, and the scale of these charts is 10.7° per inch, except for Hercules, Serpens, and Ursa Major, each of which are shown in slightly less detail.

A FIELD GUIDE TO THE STARS AND PLANETS
Handbook of the Constellations
COLLINS GUIDE TO STARS AND PLANETS
SKYGUIDE
POPULAR STAR ATLAS
THE STAR BOOK
by Robert Burnham
ATLAS OF THE HEAVENS
Star Atlas
starwatch
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MAKE YOUR OWN EASY-TO-USE STARFINDER TO LOCATE CONSTELLATIONS.
BEN MAYER

A Field Guide to the Stars and Planets, 2nd ed., Donald H. Menzel and Jay M. Pasachoff. 473 pages, Houghton Mifflin, 1983. First published in 1964, this book is one of the Peterson Field Guide series on nature. The second edition contains a general introduction to astronomy, information on planets, Moon maps, and two sets of sky maps. The first set is a collection of twenty-four large-scale maps, each measuring 8" by 6½", which show the entire sky as seen throughout the year from different latitudes. The second set contains fifty-two charts in epoch 2000, each measuring 4" by 5" and showing a total of about 25,000 stars down to magnitude 7.5 and 2,500 deep-sky objects. The scale of these charts is 7.4° per inch.

Leslie Peltier's Guide to the Stars, Leslie Peltier. 185 pages, AstroMedia and Cambridge University Press, 1986. Slanted toward naked-eye and binocular observing, this book features eight seasonal maps of the naked-eye sky and specialized maps showing variable stars.

The New Atlas of the Universe, Patrick Moore. 271 pages, Crown, 1984. Following an extensive text on all aspects of astronomy, the *New Atlas* presents four star charts each measuring 20" by 12" and covering one-quarter of the sky. Stars as faint as magnitude 6.5 and a few deep-sky objects are plotted in epoch 1950. The scale of these charts is about 9.0° per inch.

A New Popular Star Atlas, R. M. G. Inglis. 27 pages, Sky Publishing Corp., 1974. Showing some 2,500 stars as faint as magnitude 5.5 and 50 deep-sky objects, this book's eight charts are plotted in epoch 1950 and have a scale of 10.0° per inch.

Star Atlas, Jacqueline and Simon Mitton, eds. 31 pages, Crown, 1979. This volume contains eight maps showing some 4,000 stars as faint as magnitude 6.5 and about 125 deep-sky objects, but the stars appear as asterisks.

Starwatch, Ben Mayer. 144 pages, Perigee Books, 1984. *Starwatch* presents dark stars on a white background made from short-exposure photographs of twenty-four regions of the sky and reproduced in blue ink, with each facing page depicting the corresponding positive images. Each map measures 11" by 8½", and the scale of these charts is typically 2.2° per inch.

Intermediate Star Atlases

Handbook of the Constellations, Hans Vehrenberg and Dieter Blank. 197 pages, Sky Publishing Corp., 1973. Fifty-seven charts show each of the eighty-eight constellations in this book (two are required for Hydra and Eridanus, and some charts show several star groups). The charts depict 6,000 stars and 1,050 deep-sky objects in epoch 1950 coordinates, and the scale of the charts is 6.1° per inch.

Mag. 6 Star Atlas, Terence Dickinson, Victor Costanzo, and Glenn F. Chaple, Jr. Edmund Scientific Co., 1982. This book contains fifteen charts, each measuring about 11" by 11", which show stars as faint as magnitude 6.2 and several hundred deep-sky objects. The scale of these charts is 6.3° per inch, and the coordinates used are epoch 1950.

Norton's Star Atlas and Reference Handbook, 17th ed., Arthur P. Norton. 116 pages plus star charts, John Wiley & Sons, 1986. Extensive introductory information and data tables precede the eight maps that make up *Norton's Star Atlas*. The 17" by 11" two-page-spread charts show 8,400 stars as faint as magnitude 6, along with 600 deep-sky objects. The epoch used is 1950, and the scale of these charts is 7.9° per inch.

A Telescope Handbook and Star Atlas, Neale E. Howard. 226 pages, Thomas Y. Crowell, 1967. Howard's book has fourteen maps showing stars down to 6th magnitude and vellum overlays with deep-sky objects plotted in blue ink. The scale of these charts is 10° per inch. Preceding these charts is an extensive text on astronomical observing, and following them is a "gazetteer" listing several hundred stars and deep-sky objects in epoch 1970.

Advanced Star Atlases

Atlas of Deep-Sky Splendors, 4th ed., Hans Vehrenberg. 242 pages, Cambridge University Press, Sky Publishing Corp., and Trevgesell-Verlag, 1983. *Splendors* is an atlas with 114 photographs of fields containing bright deep-sky objects, virtually all of which are reproduced on the same scale of 0.4° per inch. It is one of the finest collections of deep-sky photographs available in print.

Atlas of the Heavens, Antonin Becvar. 18 pages, Publishing House of the Czechoslovak Academy of Sciences and Sky Publishing Corp., 1962. Long the standard star atlas for advanced observers, Becvar's work has been superseded by Tirion's *Sky Atlas 2000.0. Atlas of the Heavens* is useful nevertheless because it shows regions of dark nebulosity, while Tirion's atlas doesn't. The sixteen charts, each measuring 21" by 15", show 32,000 stars as faint as magnitude 7.75 and 1,850 deep-sky objects. The epoch is 1950, and the scale is 3.5° per inch.

Sky Atlas 2000.0, Wil Tirion. 28 pages, Sky Publishing Corp. and Cambridge University Press, 1981. The standard charts for advanced observers, Tirion's new atlas uses epoch 2000 coordinates and shows 43,000 stars down to magnitude 8.0 and about 2,500 deep-sky objects. The scale of these charts, each of which measures 18" by 13", is 3.5° per inch.

can always take clothes off if you're overheated, but you can't put on more clothes you didn't bring if you're too cold.

Personals

You will want to bring several items for personal comfort. A handwarmer comes in handy when the air temperature drops in the early morning. Many models are available at sporting goods and department stores, and all function about the same, burning lighter fluid and providing enough heat to keep your hands warm. If you keep a handwarmer in a pocket, you can drop a dewed-up eyepiece in alongside it and evaporate the moisture in a few minutes.

Bug spray can be another lifesaver. The best kind contains high-powered bug juice you smear on at the beginning of the night so you don't have to worry about mosquitoes for at least several hours. You can also bring an insect fogger to discourage pests from coming anywhere near you, but be careful not to spray your charts, telescopes, and other valuables with a sticky goo that never rinses off.

You may also want a small table to hold maps and loose accessories. Folding card tables work well, although ideally you want something with an edge so eyepieces can't roll off onto the ground. An observing chair or stool is helpful for avoiding fatigue. A folding chair from the local hardware store, a drummer's "throne" from a music store, or an "observing chair" from a telescope dealer serves the purpose. If you have a large telescope, get a short, sturdy stepladder to climb onto when the telescope is pointed toward the zenith. Stepladders are readily available from hardware stores.

Another helpful item is a home-packed kit containing something to eat and drink. Eating something you like helps keep you alert and gives you energy to keep observing; drinking a hot beverage helps with the cold-air problem. A warning: Do not drink alcoholic liquids while observing. Apart from the obvious drawbacks — decreased mental acuity and the possibly disastrous results from driving — alcohol rapidly and very effectively impairs one's ability to perceive details in faint light. If you're committed to observing, you might as well do it right.

So you can read star charts without losing dark adaptation, bring a good quality, reliable, red-filtered flashlight when you go observing. A look at telescope catalogs shows that many types of astronomical flashlights are available from telescope dealers, and, of course, any regular flashlight can be turned into an astronomical one by adding a filter of some sort.

One company makes a "miner's lamp," which is a flashlight attached to an expandable band that fits around a person's head. This gives you light where you look and completely frees hands for other purposes. Some come with strings for hanging the lights around your neck so they are ready when you need them.

An essential item for deep-sky observers, the astronomical toolkit, should be ready at all times in case you need to tighten a screw or remove an Allen bolt. The kit should contain a flat-bladed screwdriver, a Philips screwdriver, a jeweler's screwdriver set, an Allen wrench set, an adjustable-end wrench, pliers, needlenose pliers, and a small plastic mallet. Shown with this kit are an eye patch, handwarmer, dust brush, and level.

Most work equally well, but there are some pointers to consider when shopping for one or making one yourself.

First, the problem with most red flashlights in astronomy is that they're too bright. You don't need much light to read a star chart, and the excess light, though it may be reddish, will nevertheless impair your ability to see faint objects. Make sure the light you get for reading maps is barely bright enough to let you see your charts. Second, you may want to add a hood made of cardboard or some other flexible, opaque material to shield any glare from the flashlight. A 45°-angle hood pointed downward at the maps at all times gives you almost no exposure to glare. Third, you'll want another, brighter, red light to use when you're setting up your telescope, tearing it down, walking around, or experiencing a minor emergency such as dropping an eyepiece in high grass. Using a removable filter on the second flashlight is a good idea so you have bright white light handy if an actual emergency occurs.

If you construct your own astronomical flashlight from an ordinary, off-the-shelf model, think carefully about what material to use for the filter. One good method is simply cutting two or three disks of brown paper from a bag and inserting them between the light's diffuser and retaining ring elements. Or, you can use several layers of red cellophane plastic, a red-tinted plastic circle cut to the right size, or multiple layers of red nail polish painted over the diffuser. Any of these works better than red plastic, which tends to be *so* red it's hard to see by. Whatever you choose, make sure that the resulting light is barely bright enough to read by.

Your Telescope's Companions

What optical accessories do you really need for your telescope? First, bring an eyepiece — or a combination of eyepieces — that makes you completely happy. Be fussy. If you wear glasses, find at least one eyepiece you can observe with without having to remove your glasses. If you don't wear glasses, find eyepieces you can put your eye close to and still see the whole field of view.

Your standard eyepiece will depend on what sort of observing you do. If you like observing large, faint nebulae, your standard may be a 32mm Erfle with a 2" diameter barrel. Or it may be a 1¼" 9mm Plossl if you enjoy hunting down small planetary nebulae or examining individual stars in open clusters. Whatever your favorite eyepiece may be, make sure it's safely packed away in your observing kit before you leave home.

A good quality Barlow lens is another valuable accessory for your telescope. Whether it be a 2x or 3x Barlow, this amplification lens can, for a relatively low price, effectively double your number of eyepieces by increasing the power of the eyepieces you already have.

Deep-sky observers require a large finder scope simply because it shows faint stars, which makes finding deep-sky objects relatively easy. An 8x50 finder, 50mm aperture with 8x magnification, generally provides just enough light grasp to satisfy most star-hoppers, but an even larger finder scope helps more. However large a finder you choose, you may want to avoid getting a right-angle prism on the eyepiece end of the finder. This turns your view upside-down and makes matching the movements of stars in the finder against those of the stars in the sky needlessly confusing. Along with a good finder scope, a pair of 7x50 binoculars helps you orient yourself in the sky and find faint objects. Of course, binoculars are also useful as a separate observing instrument.

Unless you routinely observe from pitch-black skies and thus need not worry about light pollution, you may well want to add a good nebula filter or two to your list of observing essentials. Many models are available from telescope dealers, but two stand out: Lumicon's red-transmissive UHC filter for emission and planetary nebulae and the blue-transmissive Deep-Sky Filter for galaxies and reflection nebulae.

You may also want several supplementary items. A hood will keep your telescope dry on damp nights, especially if you have an SCT with a glass corrector plate on the front end. Plastic and metal dewcaps, either heated or unheated (heating helps remove the dew for longer periods), are available from dealers, but I have found that an empty cardboard Baskin-Robbins ice cream container with its bottom cut out works best, and the local store employees are happy to get rid of the containers.

A hair dryer will help remove dew from corrector plates, eyepieces, finders, and cameras, but when using one be careful not to overheat any delicate telescope parts.

A hood for yourself may help too, especially in light-polluted areas. Throwing a black cloth over your head while peering through the eyepiece eliminates scattered light that can distract you from what you see in the eyepiece. And, if you're one of those people who always closes one eye, a black eyepatch is very helpful. You can get one at medical and costume shops everywhere.

Even if you observe in your backyard, be sure to carry a simple tool kit with you. This can save an incredible amount of time, frustration, and trouble when something as simple as a loose screw or an Allen bolt stops you dead in your tracks. Your kit should contain a flat-bladed screwdriver, a Philips screwdriver, a jeweler's screwdriver set, an Allen wrench set, an adjustable-end wrench, pliers, needlenose pliers, a small plastic mallet, and plastic garbage bags — the last prove handy if a sudden rainstorm forces you to close up shop in a hurry!

Road Maps of the Sky

One of the most important accessories for observing in any season is a good star atlas — your road map of the sky. To use a star atlas, open it to the page showing the region of sky that contains the deep-sky objects you want to observe and find that general area in the real sky. Match the brightest stars in that vicinity of the sky with the corresponding ones on the chart, and then use your finder scope to zero in on the object by "hopping" from bright stars to successively fainter ones nearer the objects, using the chart as a guide along the way.

There are more than two dozen star

atlases on the market today. How should you determine which is best for your needs? Consider three factors: How experienced are you as an observer? What sort of equipment are you using? What types of objects — and how many — do you wish to find?

Your observing experience dictates the level of complexity you'll want in a star atlas. If you're a beginner, try using a relatively simple atlas that shows naked-eye stars (stars as faint as about 6th magnitude) and the several dozen brightest clusters, nebulae, and galaxies. Such an atlas lets you learn star-hopping and insures that you see the sky's best showpieces before going on to fainter, more challenging objects.

If you're already adept at star-hopping and have seen many of the brightest deep-sky objects, you may want an intermediate level atlas. This will show slightly fainter stars and many more deep-sky objects. If you're an experienced deep-sky observer and want to find as many objects as possible, then you may consider getting an advanced star atlas, one that shows stars down to 8th or 9th magnitude and thousands deep-sky objects.

Your observing equipment also influences the suitability of a particular star atlas. If you observe with binoculars or a 2-inch or 3-inch scope, you are looking at fairly large areas of sky. This limits you to viewing the several hundred brightest deep-sky objects. With small instruments many observers feel nebulae and galaxies fainter than 10th or 11th magnitude are too faint to seem worthwhile because they appear only as dim smudges, if at all. Twelfth-magnitude objects are visible in 4-inch and 6-inch telescopes, which dramatically increase the number of objects — mostly galaxies — within these instruments' grasp. A 4-inch or 6-inch scope can also operate at higher magnification than a 3-inch scope does; observers with 6-inch scopes see a smaller patch of sky than observers with 3-inch scope do.

This progression continues indefinitely. Generally, the larger the telescope you use, the more detail you'll need in a star atlas. Larger scopes show many times more stars than smaller ones do; they also show smaller amounts of sky. You'll need these faint stars on your atlas to avoid confusion about where your telescope is pointed and to assist in star-hopping to deep-sky objects that don't lie near any bright stars.

The types and numbers of objects you want to observe will also affect your choice of star atlases. If you want to observe bright double stars or large star clusters, you will need a relatively simple atlas. If you wish to find a large number of faint galaxies or small planetary nebulae, you'll need an advanced star atlas that shows hundreds of such objects.

Some of the best beginner's atlases are *Collins Guide to Stars and Planets, A Field Guide to the Stars and Planets, A New Popular Star Atlas, Leslie Peltier's Guide to the Stars,* and a book simply called *Star Atlas*. Well-known entries at the intermediate level are *Handbook of the Constellations, Mag. 6 Star Atlas, Norton's Star Atlas,* and *A Telescope Handbook and Star Atlas.* The best advanced star atlases are *Atlas of Deep-Sky Splendors, Atlas of the Heavens,* and *Sky Atlas 2000.0*. (See the bibliography on pages 66 and 67 for a comparison of the main features of these atlases.)

Recording Your Observations

You've equipped yourself to go outside under the stars and make lots of valuable observations. Now what are you going to do with those observations? Recording what you've seen is an act that will in time provide you with a valuable personal reference to your astronomical observing; not recording what you've seen simply doesn't make sense. Indeed, the very act of writing down what you see will make you a better and more careful observer. You can record observations two ways: in words and in sketches.

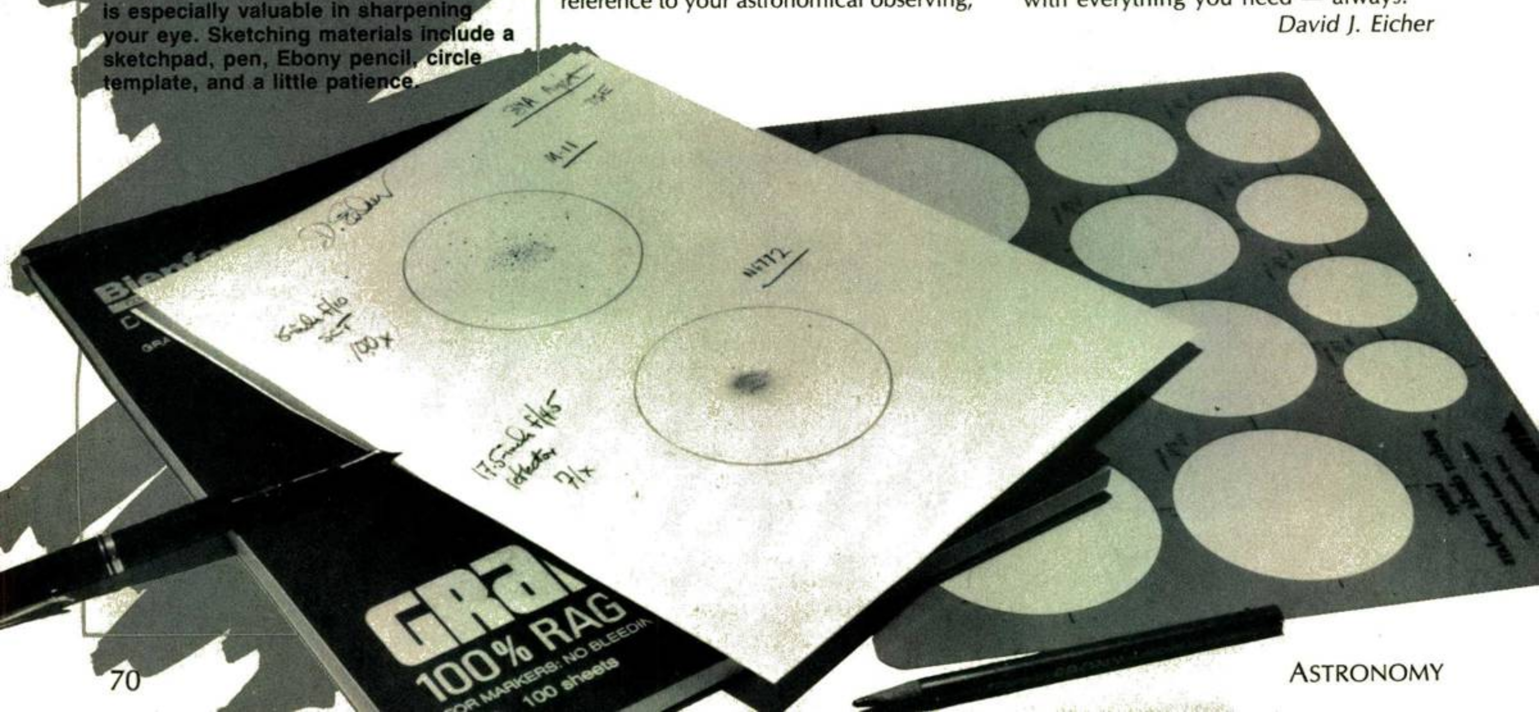
Keeping an observing diary requires only that you write a description of what you observe each night, including all pertinent information like telescope aperture, magnification, date, time, impression and description of the object. Sketching what you see at the telescope in a logbook is easy too, requiring that you buy a few simple materials and use them enough to become adept at sketching objects you see in the eyepiece.

The first item you need for deep-sky sketching is a sketchpad. The paper should have a fairly loose weave and a rough texture, enabling you to smooth out subtle details you draw. You also need a dark graphite pencil like Eberhard Faber's Ebony 6325, a stump that lets you blend graphite on paper into a realistic view of what you see (I simply use my right index finger), and an eraser for lightening areas that get too dark. The total cost for sketching materials is only a few dollars. Sketching is one of the most effective ways to record what you see in the sky. (For details on deep-sky sketching, see "Capturing Deep-Sky Objects on Paper," ASTRONOMY, February 1983.)

You should now be able to draw up a list of the things you need in addition to your telescope for observing under summer's star-filled skies. When you learn which accessories maximize your observing experience, you'll undoubtedly develop your own list of telescopic peripherals. Until then, commit to memory the basic items mentioned here, get out those moldy observing lists, dust off the star atlases, drool over the latest eyepiece catalogs, and dream about the warm, satisfying views of the Lagoon Nebula to come. And remember, arrive with everything you need — always.

David J. Eicher

Recording your observations will provide you with a valuable reference and will make you a better observer. Drawing what you see in the eyepiece is especially valuable in sharpening your eye. Sketching materials include a sketchpad, pen, Ebony pencil, circle template, and a little patience.



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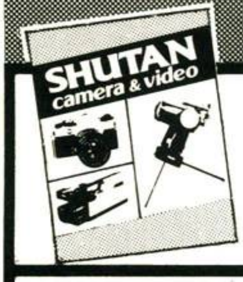
310	429	8x21	89	Barlow 126	48	Neb 911	124	SWA 18mm	149
320	529	8x32	139	Barlow 127	64	Off-axis system	169	SWA 24.5mm	159
6600	679	10x42	159	Hand contr 36	94	Solar-8" 955	249	SWA 32mm	239
2045	589	10x50	119	Drive corr 41	189	Set circle illum	48	UWA 4.7mm	159
2045 LX3	729	11x80	249	Dec 38	94	Tele extender	36	UWA 6.7mm	189
2080 GEM	895	11x80 Armored	269	Dec 38A	94	Tripod case	89	UWA 8.8mm	229
8" LX3 mcso/tr/we	1595	20x80	259	45° Prism 928	56	T-adapt-8"	36	UWA 14mm	269
10" LX3 mcso/tr/we	2450	20x80 Armored	299	Filter set 6-1¼	84	Weight system 8"	96	SER II 4 to 25mm	50
DS-16A	1995	30x80	279	LED Map light	32	WFAS	109	4000 2x or 2.8x	84

(Prices subject to change, limited to stock on hand.) (Camera shown on 2045 LX/3 is not included.)



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Photography
in
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Hidden Images: Dissecting Bright Nebulae

by Robert Reeves

Many people believe complicated darkroom techniques are required to produce exceptional astrophotos of a bright nebula. Yet the simple technique of making several prints, each with a different exposure time, can bring out details normally hidden from view. Each print reveals a different aspect of the nebula so, when it is placed in the context of a series, the whole becomes greater than the sum of its parts.

At one time or another any astrophotographer who does black-and-white darkroom work has mistakenly overexposed a print of a bright nebula. The resulting print depicts a shrunken ghost of the total nebulosity contained on the negative. Since showing the full bloom of nebulosity and images of the faintest stars are the goals of most astrophotographers, the overexposed prints usually end up in the trash.

Just a few years ago, however, astrophotographers were after quite different results. If you take a look at the astrophotos in the early issues of ASTRONOMY, for example, you'll notice the photographers were more concerned with making the sky background black, even if that meant losing fainter stars and some of the outer nebulosity. By current standards they were overexposing their prints, but the result was closer to what an observer actually sees in the eyepiece.

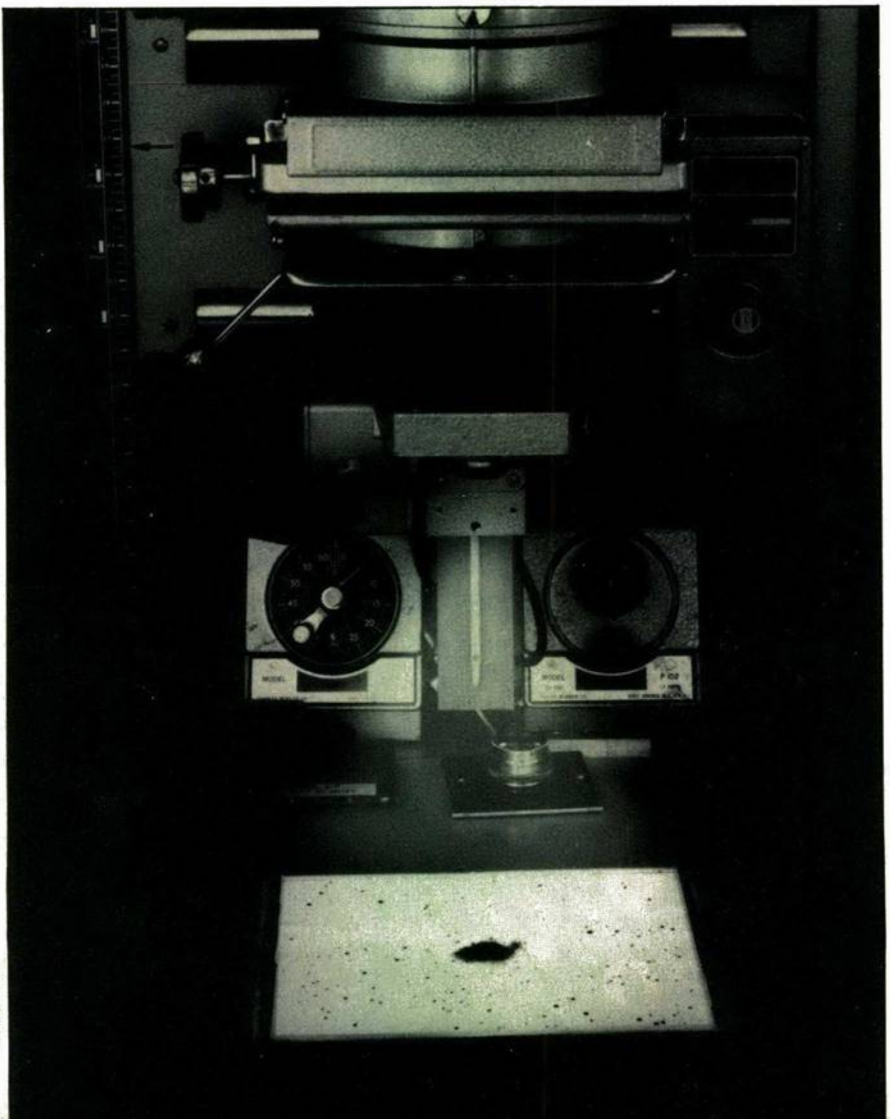
Unlocking the Hidden Image

I have recently discovered the value of systematically overexposing prints of bright nebulae: by progressively overexposing a series of four or five prints, I can peel back layer after layer of the obscuring outer nebulosity and see what lies within. Instead of keeping one final print, I end up with a sequence that collectively shows more detail than any single photo could ever show.

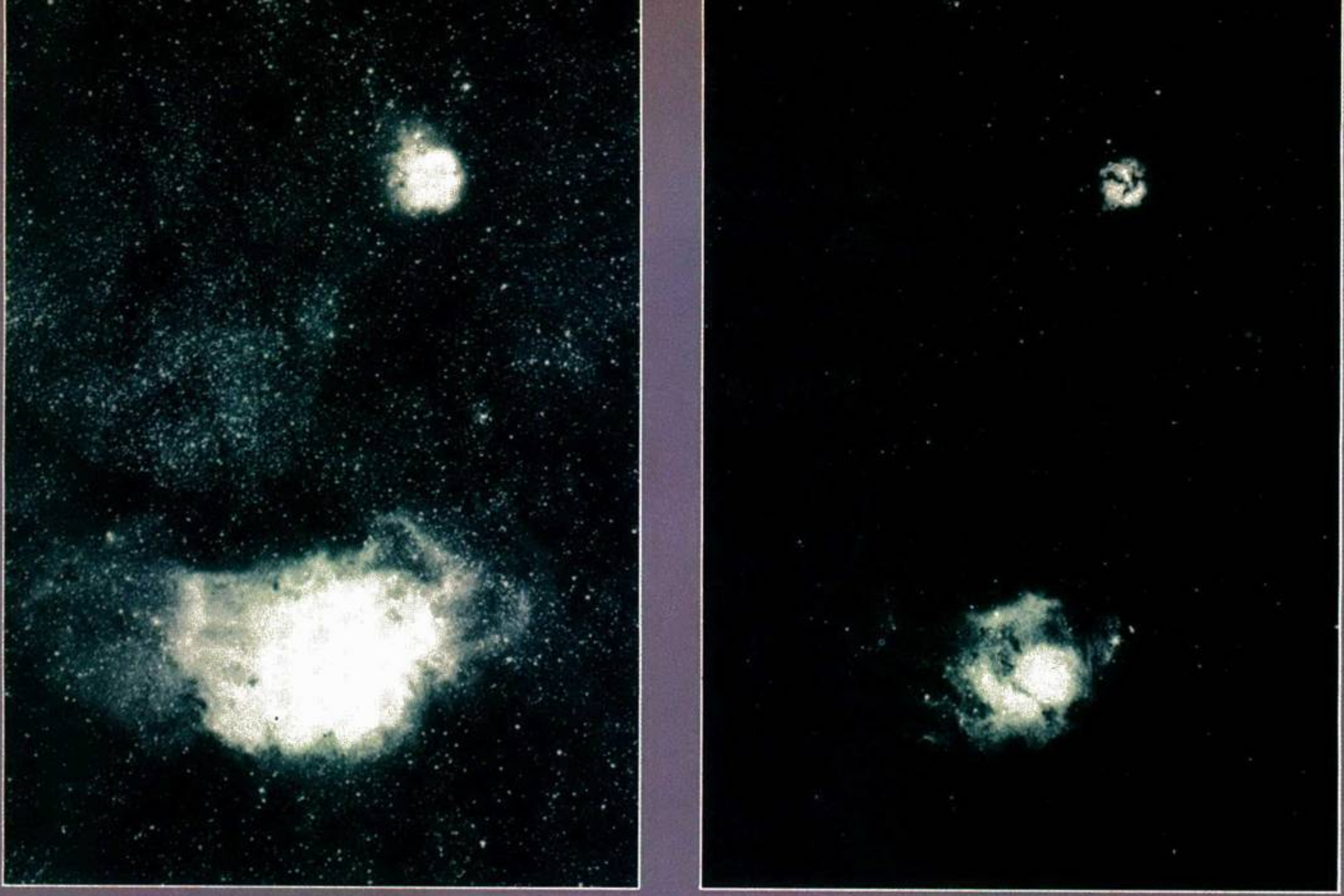
Depending on the object you're "dissecting," you may find that stripping off the outer layers reveals a hidden star cluster or dense, highly detailed clouds at the heart of the nebula.

For instance, the photos of the Lagoon and Trifid nebulae (M-8 and M-20) on the opposite page illustrate the kind of information revealed by lengthening the exposure time in printmaking. When exposed to show the maximum nebulosity, the photograph reveals the outer tendrils of the Lagoon extending for quite a distance and several dense star clouds. However, the detail at the centers of the nebulae is virtually lost. When the print is highly overexposed, the sky background darkens noticeably and the star clouds disappear. But now a fair amount of

If you normally do your own darkroom work, revealing the images hidden in your astronomical negatives is as easy as making extra prints. The only necessary piece of equipment is the enlarger that makes the prints from the negatives.



Art Schmidt



The Lagoon and Trifid nebulae are good subjects for demonstrating the effect of changing exposure time in the print-making process. In the "properly" exposed print (left) all the nebulosity is visible. Internal detail may remain on the negative, however, and by overexposing the print (right), we can bring it out. All photos by Robert Reeves.

structure is visible in the Lagoon, and the open cluster NGC-6530, which supplies the nebula's energy, begins to show. In the overexposed print the Trifid is also more detailed — the dark dust lanes that give the nebula its name are apparent.

Each of the photo sequences on pages 74 and 75 reveals more information than the leftmost, properly exposed print does alone. Wisps of nebulosity spread throughout the entire region of the Horsehead Nebula (B-33), but much of the detail in this object is hidden by the overall brightness of the first image. Only as the prints are made darker does the collision zone between the dark cloud at bottom and the bright emission nebula IC-434 at top become more defined.

The Rosette Nebula (NGC-2237) series illustrates a more common feature revealed by this technique. In the opening photo little of the interior region can be seen because the faint nebulosity in this area is printed so brightly. Each successive print probes deeper into the interior, gradually revealing the open cluster NGC-2244 at the center. Notice that the dark dust lanes and Bok globules embedded in the wreathlike nebulosity also become more prominent as the prints are exposed longer.

The area surrounding Gamma (γ) Cygni is rich in bright emission nebulae. On a short exposure print these are the dominant features, and most of the region is bathed in a soft glow coming from gaseous hydrogen. As the prints become darker, only the brightest areas of emission remain visible — a much closer representation of what an observer sees through the telescope. Gamma Cygni itself (the bright star at right center) comes clearly into view after having been lost in the blaze of nebulosity on the first photo, while the open cluster NGC-6910 slowly emerges at the top of the photos north of Gamma Cygni.

Dissection in the Darkroom

An inviting aspect of this technique is its simplicity: if your darkroom is equipped to make prints of negatives, you already have all the equipment you need. With a little extra effort and the photographic supplies for making the additional prints, you'll be all set.

The key to making a series of photographs that probe progressively deeper into a bright nebula is using Kodak Technical Pan 2415 film. (See "Astrophotography with Tech Pan 2415 Film," ASTRONOMY, July 1986.) This emulsion is capable of retaining great detail even in the seemingly washed out bright areas of a nebula. This detail merely needs to be "burned in" during the printing process. Printing on a very high-contrast paper, such as Kodak's Kodabrome II RC printing material, F-5 grade, helps to further reveal the hidden details.

To dissect a bright nebula in your darkroom, first make a properly exposed "straight" print of the object — one that shows the maximum nebulosity only after it has been fully developed. Do not take the print out of the developer early; instead, adjust the exposure time so the print develops in no less than 60 seconds. (For fiber-based papers, development is not complete in less than 2 to 3 minutes.)

Next make a series of prints that are exposed 1.25, 1.5, 1.75, and 2.0 times longer than the original print. (For instance, if the print displaying the maximum nebulosity was exposed for 20 seconds, the exposures for the series would run 25, 30, 35, and 40 seconds.) Each of these should then be developed for the same length of time used for the first print. If the nebula looks as if it can be penetrated further, make some prints with an even greater degree of overexposure until the object has been stripped to its core.

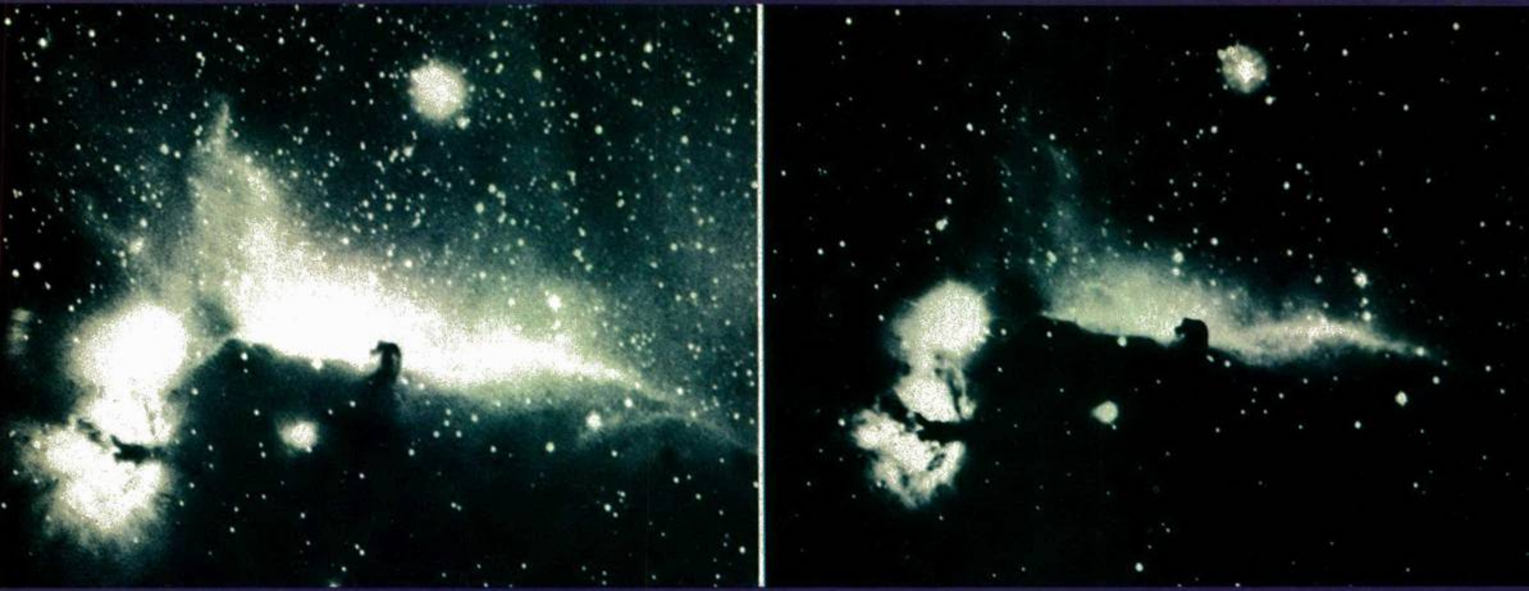
The resulting series of images, displayed in the order of penetration, will show a visually interesting and informative breakdown of deeper and deeper layers of the bright nebula. By displaying all the information held on the negative and not just what shows on one print, you will gain a greater appreciation for the objects you photograph and a worthwhile project to occupy those inevitable cloudy nights.

Robert Reeves, a frequent contributor to ASTRONOMY, is an astrophotographer and telescope maker from San Antonio, Texas. His most recent article, "In Search of Dark Nebulae," appeared in the December 1986 issue.

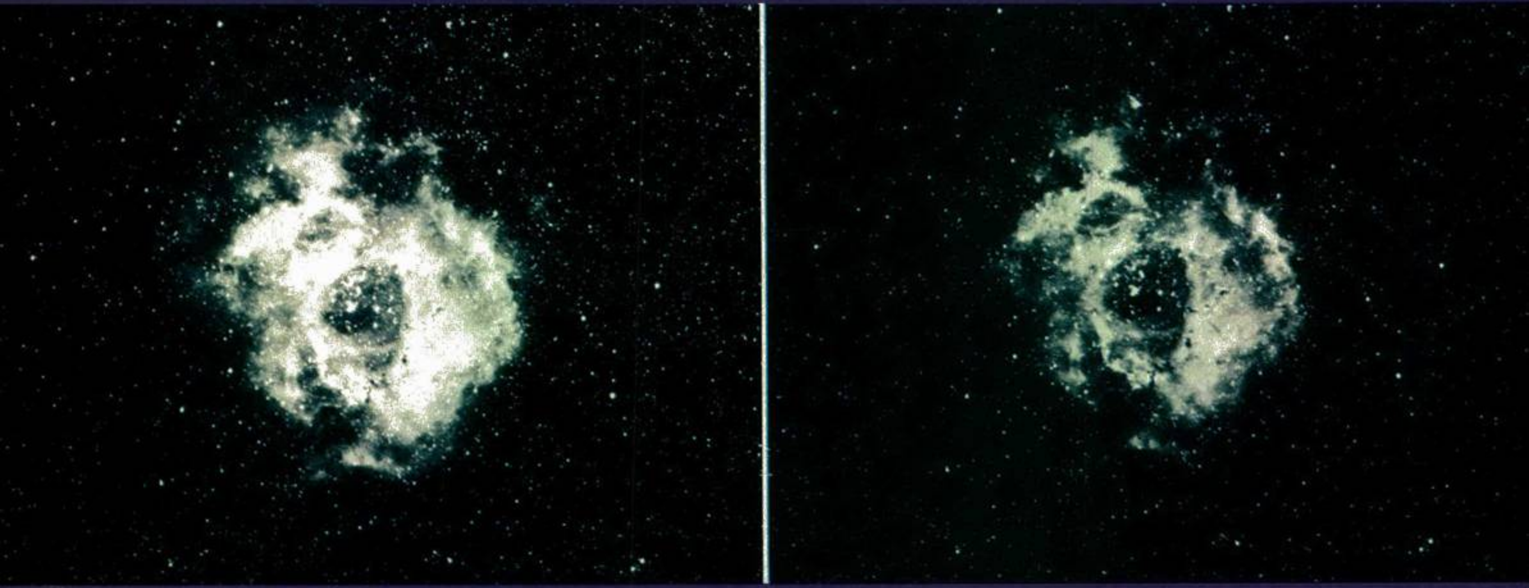
HORSEHEAD NEBULA

Full Exposure

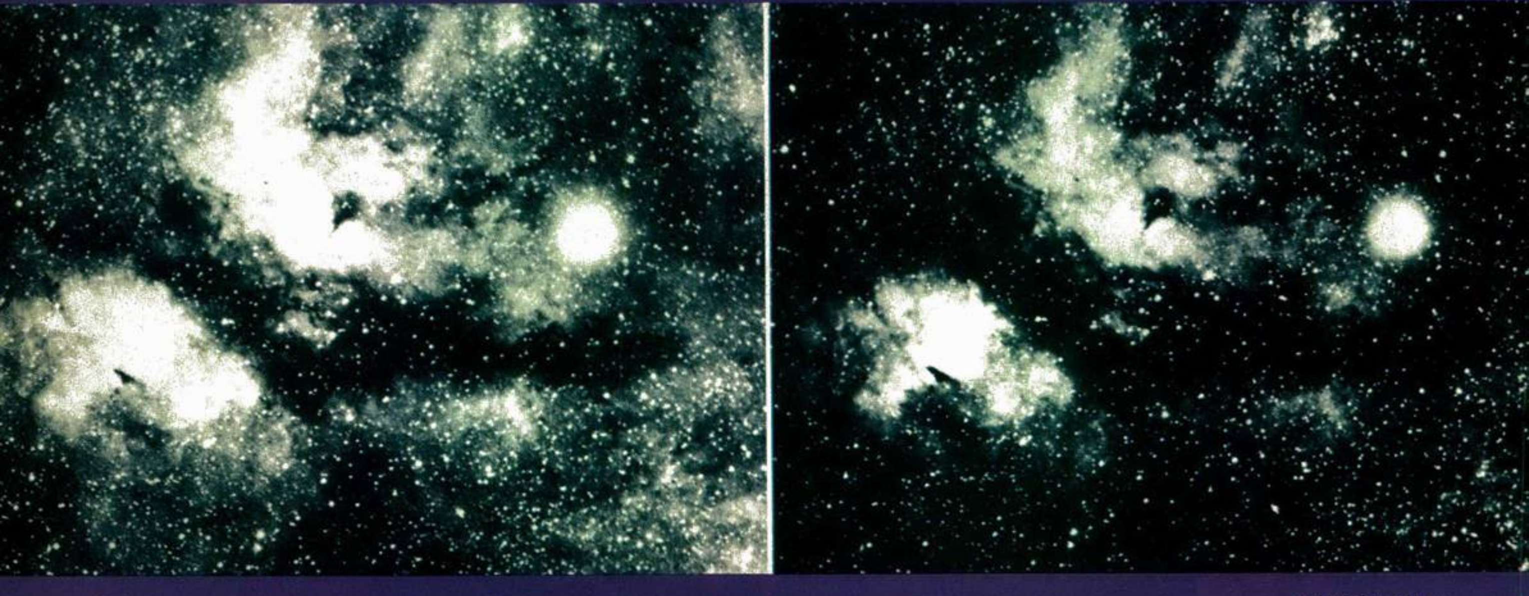
1.5x Exposure

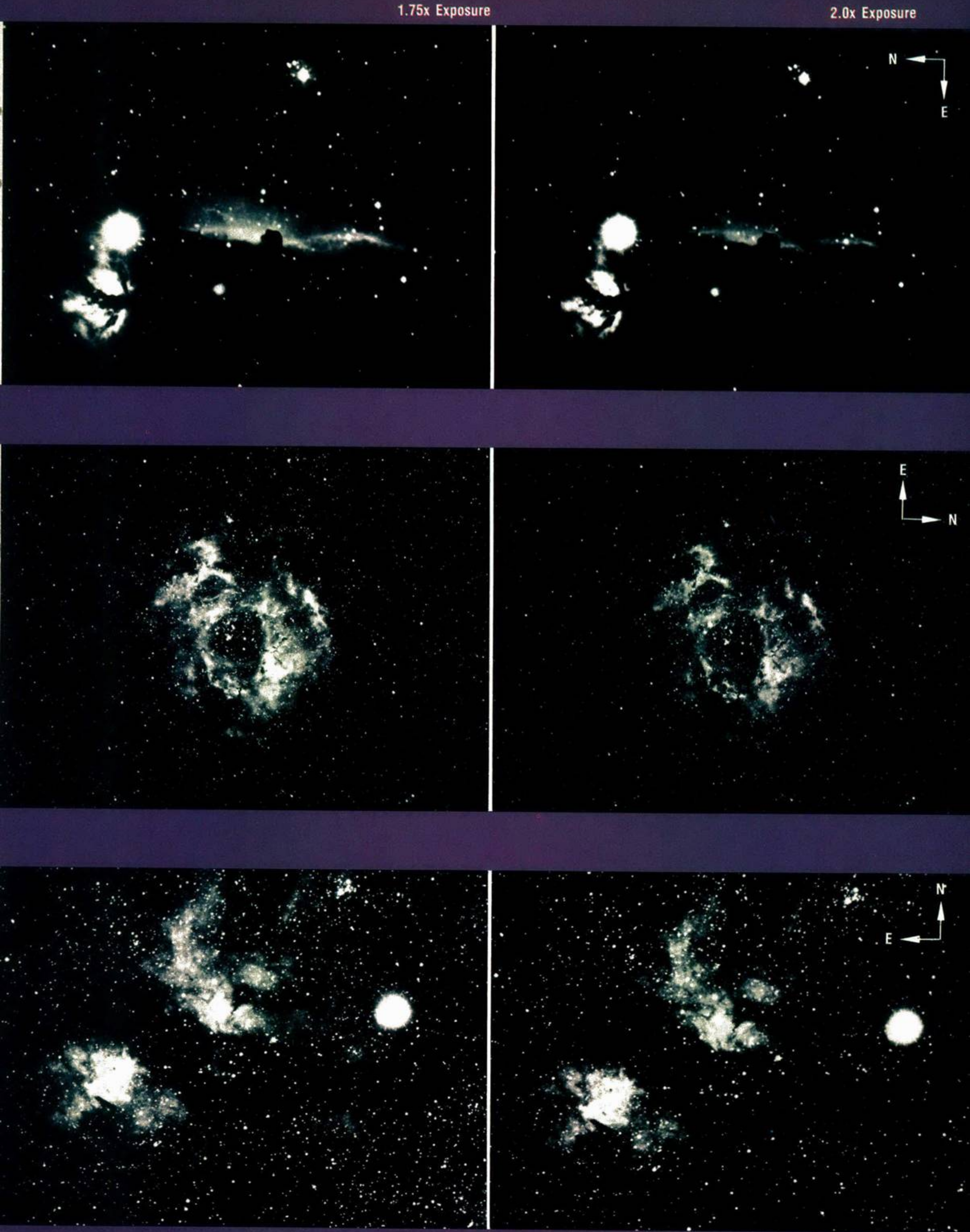


ROSETTE NEBULA



GAMMA CYGNI REGION




1.75x Exposure
2.0x Exposure
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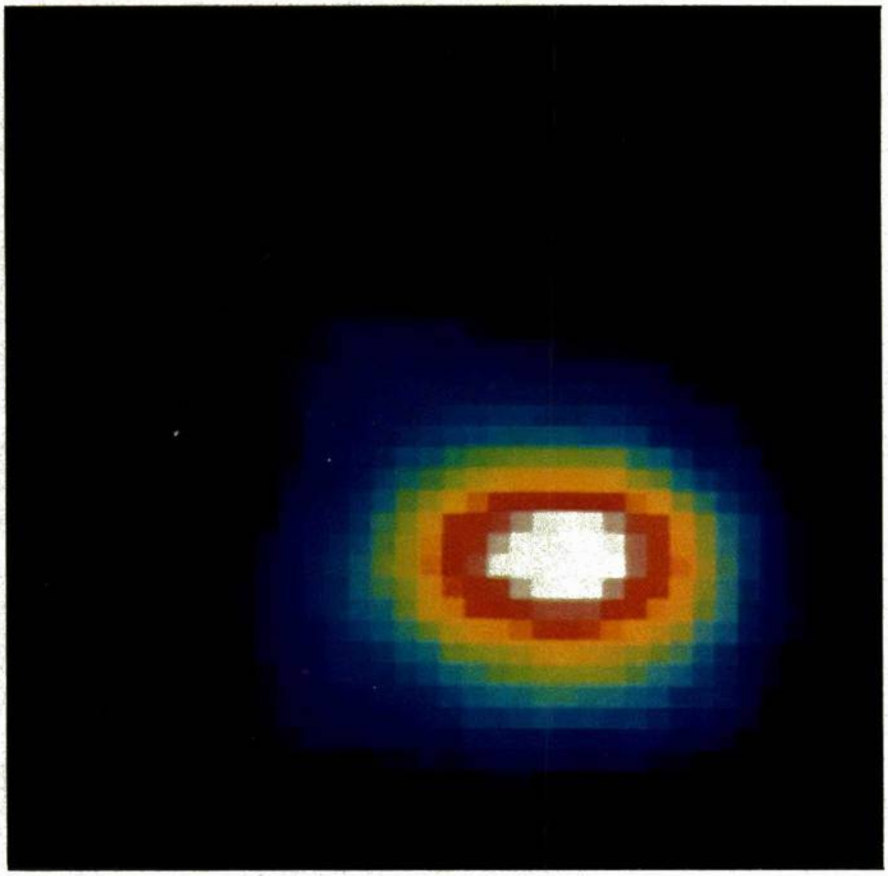


Ejected more the 25,000 years ago, the immense shell of dust particles surrounding the red supergiant R Coronae Borealis stretches across 8 parsecs of space. This false-color image from the Infrared Astronomical Satellite shows the dust cloud as it appears at a wavelength of 100 microns. Photo courtesy of the National Optical Astronomy Observatories and the Jet Propulsion Laboratory.

Fossil Stellar Shell Stumps Astronomers

Using data gleaned from the Infrared Astronomical Satellite (IRAS), astronomers have discovered an enormous "fossil" shell of cool dust surrounding a bright variable star in the Corona Borealis constellation. The shell is believed to have been ejected by the star in a process spanning 125,000 years and ending about 25,000 years ago.

Writing in the November 15, 1986, issue of the *Astrophysical Journal*, Frederick C. Gillett and Dana E. Backman of Kitt Peak National Observatory, Charles Beichman of the Jet Propulsion Laboratory, and Gerry Neugebauer of the California Institute of Technology, tentatively identify the dust cloud as "a fossil remnant of the hydrogen-rich envelope" of the supergiant R Coronae Borealis.

A false color version of the IRAS image of R Coronae Borealis reveals the shell to be remarkably symmetrical, with the surface brightness decreasing smoothly with distance from the star. Seen at wavelengths of 60 and 100 microns, the shell has an apparent diameter of about 18 arcminutes and is centered on the star. At an estimated distance of roughly 1.6 kiloparsecs, this means the shell must be some 8 parsecs in diameter. If R Coronae Borealis were placed where the Sun is, its outer shell would encompass not only our solar system but some fifty nearby star systems as well.

"This shell is very much larger than the shells of planetary nebulae," says Gillett, referring to the ionized shells of gas cast off by many dying stars. "It is a hundred times larger, and we think, much older. We're seeing a remnant of an event that happened a long time ago . . . but we're seeing it still sufficiently intact so we can infer the star to be its source."

The fact that it took 125,000 years for R Coronae Borealis to cast off its shell (as determined by the total mass of the shell and the mass-loss rate) goes against the prevailing theory, which holds that such stars abruptly lose their outer, hydrogen-rich layers as their cores collapse and begin fusing heavier elements. However, hydrogen has yet to be found in the R Coronae Borealis shell, and it must be found to prove the envelope-ejection hypothesis. Obtaining optical spectra to detect hydrogen lines will be extremely difficult because the cloud emits predominantly infrared radiation.

R Coronae Borealis happens to be the prototype of a class of some thirty stars that exhibit episodic dimming, typically of about four magnitudes, at irregular intervals. Since the 1930s astronomers have believed the brightness fluctuations of these hydrogen-deficient stars were due to an ejected cloud of carbon particles obscuring the star's light. However, the IRAS data puts a kink in this theory, at least concerning the nature of the shell surrounding R Coronae Borealis.

"We tried to figure out whether this current process could have produced the emissions we saw as a fossil shell and decided it could not," Gillett says. "Therefore, the process that built the extended shell had to be different from the one going on today."

The IRAS data also indicates that the temperature of the dust grains in the shell — 25 to 30 K — is remarkably constant throughout. This implies that the shell is not being heated by R Coronae Borealis itself, but by some external radiation source. According to Gillett, *et al.*, the amount of this heating is more than ten times what one would expect from interstellar radiation fields in the Sun's neighborhood.

"The heating could just possibly be caused by the star," says Gillett, "if the dust grains were small enough and the composition of the shell were sufficiently peculiar. But we don't think this is likely. On the other hand, we can imagine ways to increase the interstellar radiation field by small amounts: by illumination from sources hidden from us in the plane of the Galaxy, for example, or a much stronger, general intergalactic radiation field. But there is no other evidence for the existence of such a field. It's a real puzzle how the shell is heated."

Space Telescope Amateur Proposal Deadline Extended

Amateur astronomers will have three extra months to prepare their preliminary proposals for using the Hubble Space Telescope. The deadline for proposal submission has been extended from March 31 to June 30, 1987.

The deadline was changed (and the review cycle lengthened) so the amateur deadline would correspond to the newly revised proposal review cycle for professional astronomers. The Space Telescope is scheduled for launch in November 1988.

Amateur astronomers interested in getting application forms and proposal guidelines should send $1 (for postage and handling) to: Hubble Space Telescope Amateur Astronomers Working Group, c/o American Association of Variable Star Observers, 25 Birch Street, Cambridge, MA 02138.

Overcoming Radio Noise at the Arecibo Dish

To increase radio telescope and radar astronomy sensitivity, the Cornell University operators of the Arecibo Observatory in Puerto Rico want to build a fence around the telescope's reflector and add subreflectors.

The construction of a 60-foot high wire-mesh screen around the rim of the 1,000-foot wide reflector would shield the telescope from the unwanted radio and radar signals that originate on Earth, according to scientists at the National Astronomy and Ionosphere Center.

Arecibo is susceptible to interference at angles close to the surface. Some of the radio noise comes from the telescope's transmitters themselves and echoes back from surrounding hills and the ocean surface; outside sources of electromagnetic energy also cause interference. According to astronomers, the new screen and subreflectors would eliminate nearly all this interference. The upgraded observatory will be able to detect features as small as one kilometer on the cloud-shrouded surface of Venus, for example.

The proposed construction of a 60-foot-high fence around the Arecibo radio telescope in Puerto Rico would increase the sensitivity of the world's largest single-dish radio-radar telescope.

The fence can be built in two years, without disturbing observations made at the telescope, the largest radio-radar telescope in the world. Also during that time the detailed plans for the second phase of the proposed upgrading — the addition of subreflectors — would be completed.

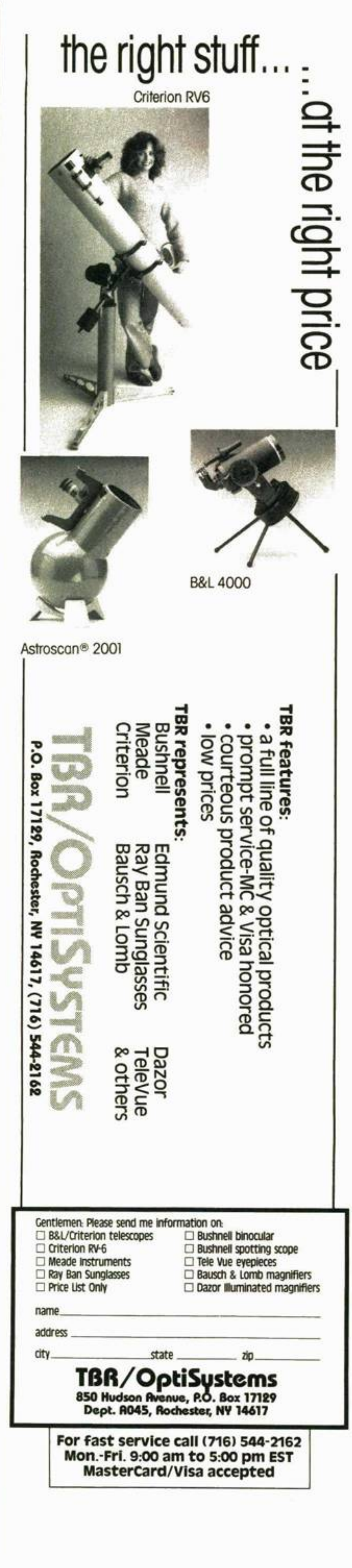
Both the wire-mesh fence and the subreflectors could increase radio telescope sensitivity by a factor of 3 to 10 and radar astronomy sensitivity by a factor of 6 to 40, according to astronomers.

About three-quarters of the telescope's observing time is spent on radio astronomy: detecting electromagnetic signals from distant objects like pulsars, galaxies, interstellar clouds, and quasars. Radar signals beamed from Arecibo toward objects in the solar system reveal surface details, distances, and chemical composition of planets, rings, and satellites.

The estimated cost of the fence is $1.56 million, and the addition of the subreflectors will bring the total upgrading cost to between $10 million and $15 million.

Did Martian Life Form in Ice-Covered Lakes?

A precondition for the evolution of life — liquid water rich in dissolved oxygen and nitrogen — could have existed on Mars despite its history of subfreezing



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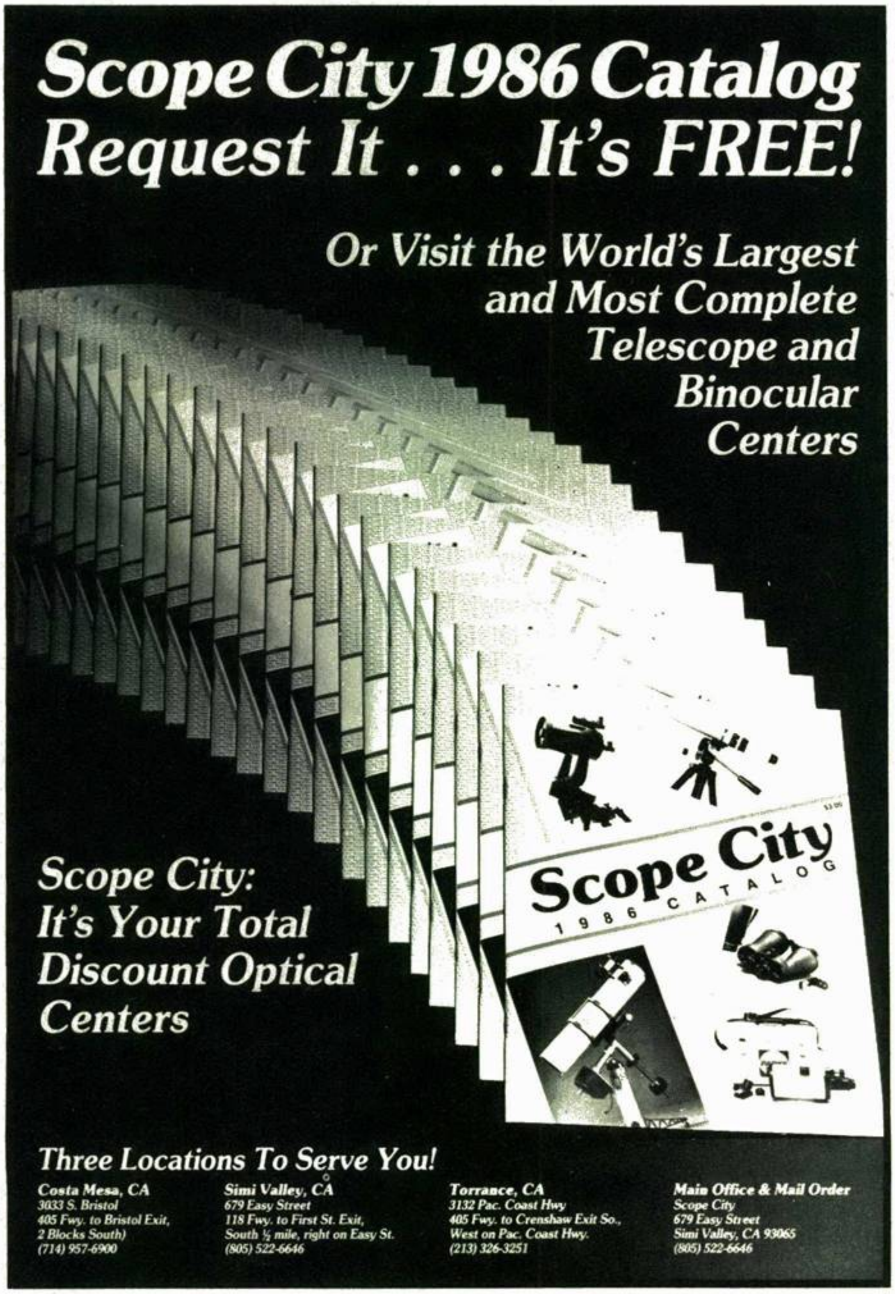
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surface temperatures, according to scientists at NASA's Ames Research Center in Mountain View, California. A complex process that keeps water warm and single-celled plants alive in Antarctic lakes could have also given life a chance to start in ancient Martian lakes.

NASA researchers Christopher McKay and Robert Wharton studied seven lakes in the dry valleys of Antarctica, an area that receives less than 4 inches of precipitation a year. The lakes, covered by over 10 feet of ice, maintain stable temperatures well above freezing with the warmest reaching a temperature of 77° F. Oxygen levels three times those of normal and nitrogen levels one and a half times those of normal were measured in these lakes.

Photographs of the Martian surface indicate large lakes may have existed in a 3,000-mile-long canyon called Valles Marineris. Viking images of this area show layered sediments on the canyon floor, which, scientists believe, were deposited in standing water. "It's quite conceivable there are microfossils in the sediments," McKay believes.

The liquid water in the Antarctic lakes is warmed as the top layer of ice sublimates and the water beneath the ice freezes, transferring heat to the liquid water below. The blanket of ice, which also traps heat from the Sun, prohibits gas exchange with the atmosphere so the upper levels of the lakes are supersaturated with gases.

New Asteroid/Comet Survey Most Comprehensive Yet

The most comprehensive survey of comets and asteroids ever conducted was carried out by the Infrared Astronomical Satellite (IRAS). It was the largest, most uniform, and least biased survey of any yet made.

The satellite scanned approximately 96 percent of the sky in four different infrared wavelengths. The large number of sightings and the nearly complete sky coverage provided an excellent sampling of the spatial distribution of the objects.

The survey was conducted by Dennis Matson, Glenn Veeder, and Edward Tedesco of the Jet Propulsion Laboratory; Larry Lebofsky of the University of Arizona; and Russell Walker of Jamieson Science and Engineering. It was presented at the fall meeting of the American Geophysical Union in San Francisco.

This is the first survey to observe infrared, or thermal, emissions and thereby avoids the strong bias in surveys made at visual wavelengths toward objects that are light in color and therefore highly reflective. Objects with a high reflectivity predominate in visual surveys because they reflect a larger percentage of sunlight and thus appear brighter.

There were 11,499 sightings of known asteroids made. Of these, 7,015 met the stringent requirements necessary to be listed in the asteroid catalog. Of the 384 comet sightings, 131 met the catalog standards. These sightings represent observations of twenty-two individual comets.

The researchers expect the data to provide a new basis with which to assess the location and potential numbers of both asteroids and comets in the solar system.

Color This Quasar Infrared

The first of what may be a new class of quasar — one that emits most of its energy in the infrared portion of the spectrum — was discovered recently on the western border of Bootes. Dubbed 13349+2438, the object was initially uncovered in 1983 during a survey by the Infrared Astronomical Satellite (IRAS).

At first no one suspected that 13349+2438 was an exceptional object. It was only when Charles Beichman, Baruch Soifer, George Helou, Thomas Chester, and Gerry Neugebauer of the California Institute of Technology; Frederic Gillett of the National Optical Astronomy Observatory; and Frank Low of the University of Arizona began examining a sample of previously unidentified IRAS sources that the object's true nature was revealed. The results of this research were reported in the September 1, 1986, issue of *Astrophysical Journal Letters*.

Quasars are relatively bright objects located at vast distances from Earth, which implies they must be releasing enormous amounts of energy. This energy is usually distributed throughout the ultraviolet, visible, and infrared parts of the spectrum and is strong in the radio region in about 10 percent of all quasars. The most noteworthy feature of this energy distribution, however, is the strong ultraviolet emission, which is unusual for astronomical objects.

Its unusually high emission of infrared radiation sets 13349+2438 apart from other quasars: 90 percent of its energy output is given off at infrared wavelengths, a far greater value than seen in other quasars. Despite this atypical behavior the researchers confirmed that this object is a quasar through other spectral characteristics.

The peak of this quasar's emission lies between 4.8 and 100 microns wavelength. Although the discoverers can not prove the source of the infrared emission is warm dust, they are strongly inclined in this direction. Presumably, 13349+2438 is a more-or-less typical quasar surrounded by a cloud of obscuring dust. As the dust grains absorb the quasar's energy they are heated, which causes them to give off the infrared radiation.

Another unusual aspect of this quasar is its exceptionally small redshift, which is an indication of how far it is from Earth.

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From a detailed analysis of the quasar's spectrum, the researchers determined its redshift to be 0.107, which corresponds to a distance of approximately 430 megaparsecs. It is much closer than most quasars and this may mean some quasars are still forming. (Since most quasars are very far away, they have been viewed as objects active only in the early universe.)

If this object represents a new class of quasar, then quasars may also be more numerous than previously thought. Using statistical methods, the researchers made a crude estimate of the space density of infrared-bright quasars. They conclude there could be one-third as many of these infrared quasars as those with an excess of ultraviolet emission. If this is true, infrared astronomy will play a significant role in future quasar research.

ASTRONOMY
AstroCalendar

February 4-March 15
"25 Years of Space Photography" (140 photographs taken by unmanned spacecraft; exhibit organized by the Baxter Art Gallery at the California Institute of Technology and sponsored by IBM), Exploratorium, San Francisco, California. Contact: Joe Ansel, 3610 Lyon Street, San Francisco, CA 94123. Phone: (415) 563-7337.

March 14
Astrophoto VII (symposium on amateur astrophotography, sponsored by Ventura Co. Astronomical Society and Orange Co. Astronomers), Moorpark College, Moorpark, California, at 8 a.m. Contact: VCAS/Astrophoto VII, P.O. Box 982, Simi Valley, CA 93062.

April 21-24
24th Space Congress (Space — The Challenge, the Commitment; sponsored by the Canaveral Council of Technical Societies), Cocoa Beach, Florida. Contact: Leslie Neihouse, P.O. Box 1333, Cocoa Beach, FL 32931. Phone: (305) 783-0220.

April 23-25
Middle Atlantic Planetarium Society (annual meeting), Centerport, New York. Contact: Vanderbilt Planetarium, Little Neck Rd., Centerport, NY 11721.

April 24-26
Astronomy Weekend (star parties for beginning and advanced stargazers), Blackwater Falls State Park, Davis, West Virginia. Contact: Pat Northeimer, P.O. Box 490, Davis, WV 26260. Phone: 1-800-CALL-WVA.

April 25
Family Astronomy Day (sponsored by the Custer Institute Astronomy Group), Custer Institute, Southold, Long Island, New York. Contact: Warren Hamburger, 2280 South Grand Avenue, Baldwin, NY 11510. Phone: (516) 223-7878.

April 25
1987 Convention of the North Central Region of the Astronomical League (hosted by the Racine Astronomical Society of Racine, Wisconsin), Racine, Wisconsin. Contact: Elsie Howard, 1505 Windsor Way #3, Racine, WI 53406. Phone: (414) 886-3368.

May 9
14th Annual Astronomy Day. Contact: Gary E. Tomlinson, Astronomical League, Chaffee Planetarium, 54 Jefferson S.E., Grand Rapids, MI 49503.

May 21-22
19th Annual Riverside Telescope Makers Conference (sponsored by the Riverside Astronomical Society and the San Bernardino Valley Astronomers), Camp Oaks, Big Bear, California. Contact: Cliff Holmes, 8642 Wells Ave., Riverside, CA 92503. Phone: (714) 689-6893.

May 22-24
1987 Conference of the Royal Astronomical Society of New Zealand. Contact: Conference Registrar, 1987 R.A.S.N.Z. Conference, P.O. Box 2241, Wellington, New Zealand, 6000.

June 12-13
17th Annual Apollo Rendezvous and Telescope Fair (sponsored by the Miami Valley Astronomical Society and the Dayton Museum of Natural History), Dayton, Ohio. Contact: Robert Sponseller, MVAS, 2629 Ridge Avenue, Dayton, OH 45414. Phone: (513) 879-5645.

July 11-17
Joint Conference of the Astronomical Society of the Pacific, the Astronomical League, and the Western Amateur Astronomers, Pomona College, Pomona, California. Contact: Andrew Fraknoi, Summer Meeting, A.S.P., 1290 24th Ave., San Francisco, CA 94122. Phone: (415) 661-8660.

July 16-24
Space Week '87 ("Space: In Service of Man"). Contact: Jim Harris, Florida Space Society, P.O. Box #291, Sharpes, FL 32959. Phone (message only): (305) 455-3390.

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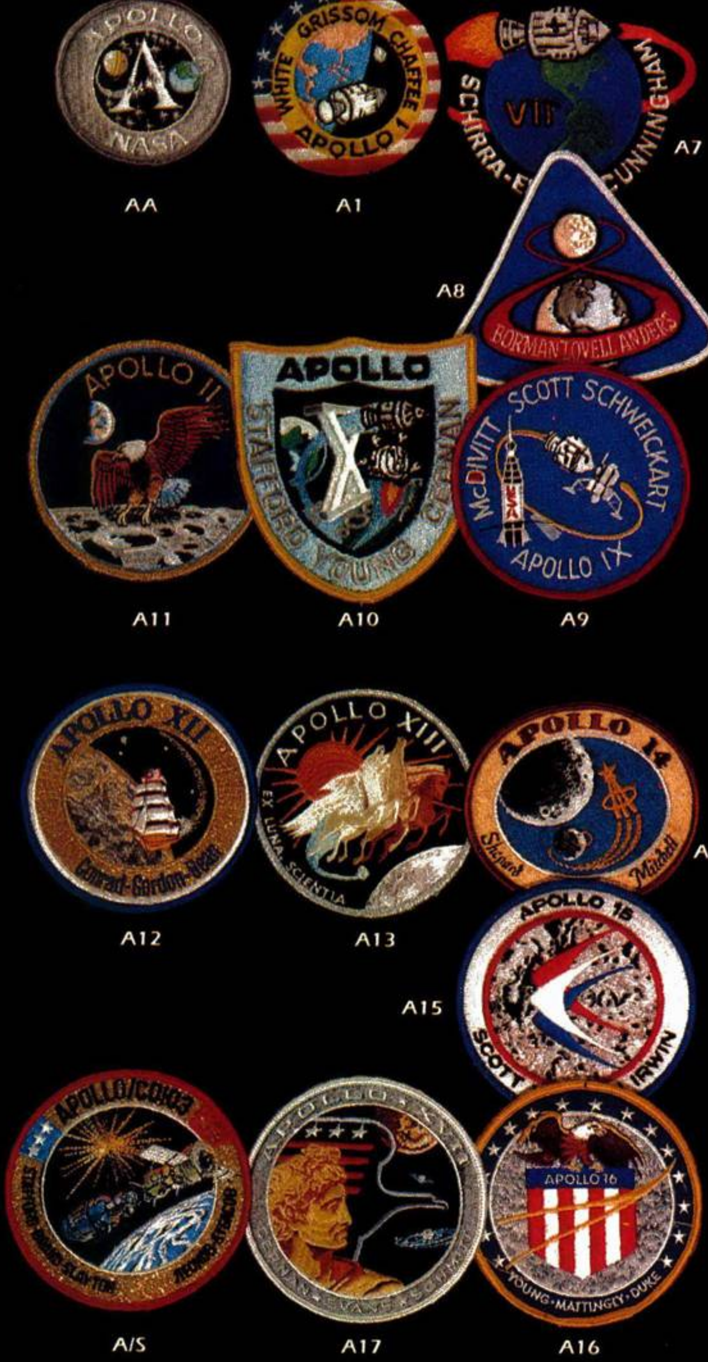
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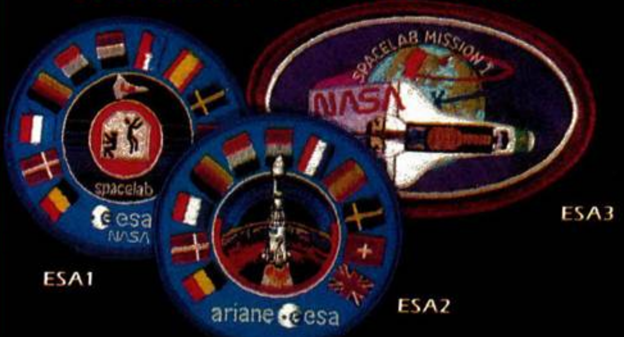
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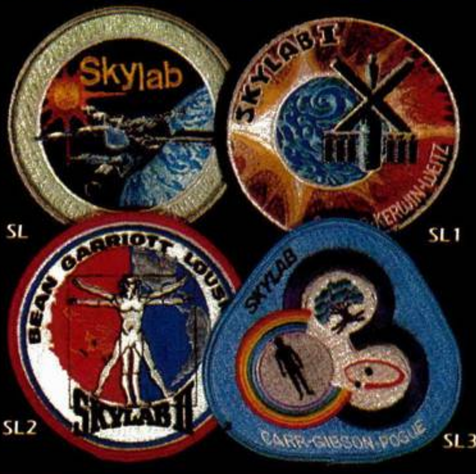
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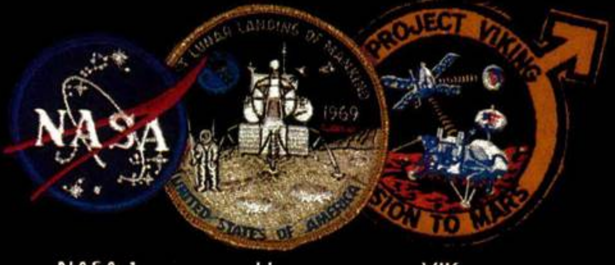
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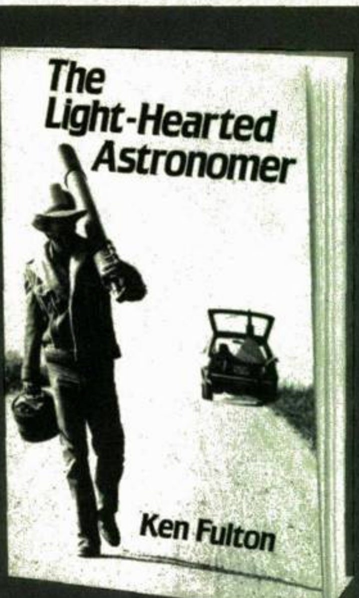

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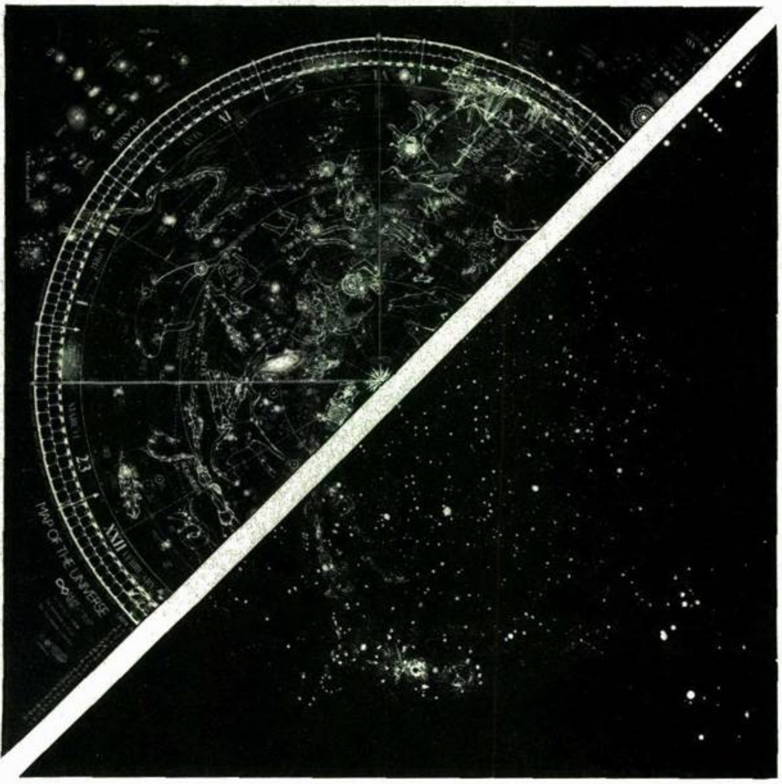

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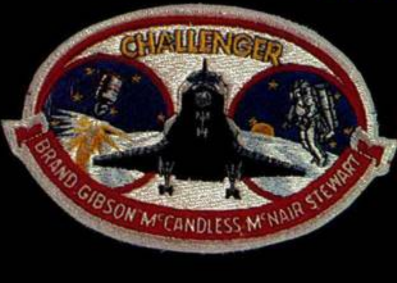
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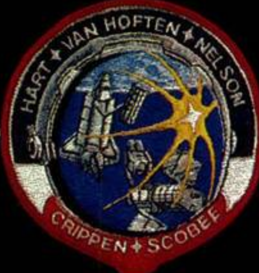
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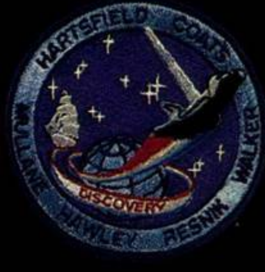
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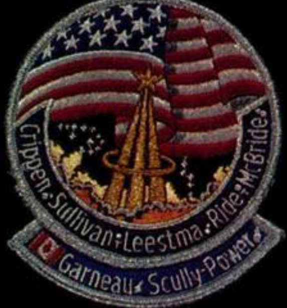
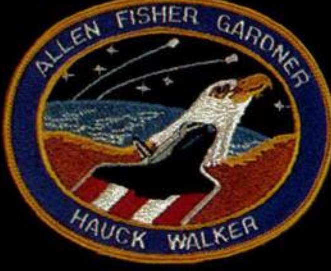
STS 41D


Crippen Sullivan Leestma Ride McBride
Garneau Scully-Power

STS 41G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HAUCK WALKER

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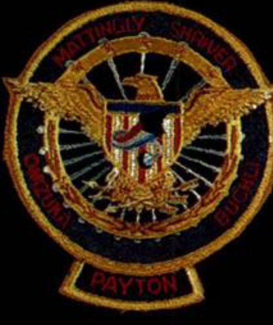
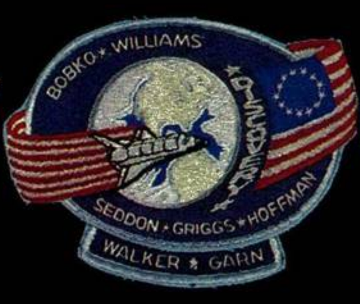

MATTINGLY SHRIVER
ONIZUKA BUCHLI
PAYTON

STS 51C


BOBKO WILLIAMS
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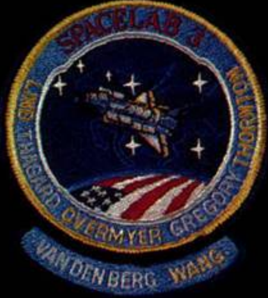
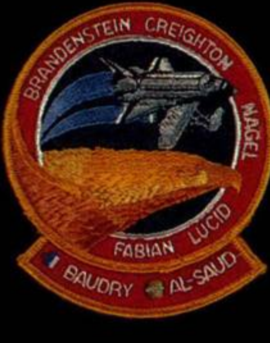

SPACELAB 3
LIND THAGARD OVERMYER GREGORY THORNTON
VAN DEN BERG WANG

STS 51B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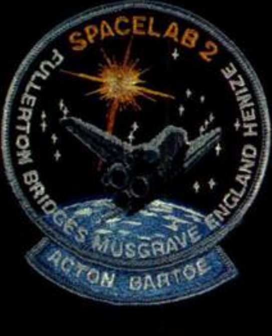
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FULLERTON BRIDGES MUSGRAVE ENGLAND HENIZE
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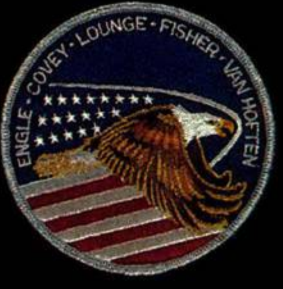
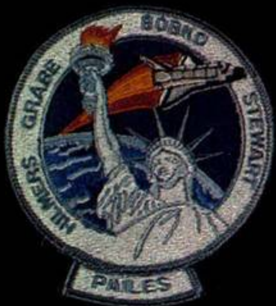

ENGLE COVEY LOUNGE FISHER VAN HOFTEN

STS 51I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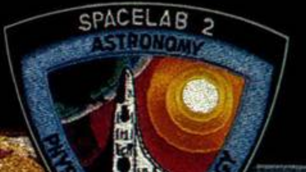
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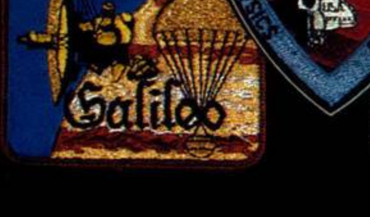

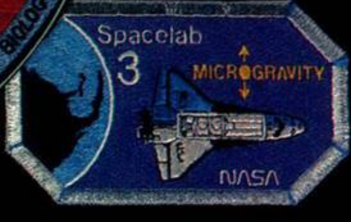
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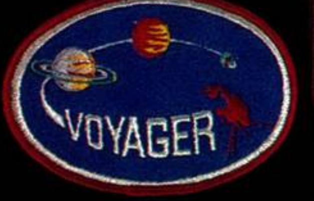

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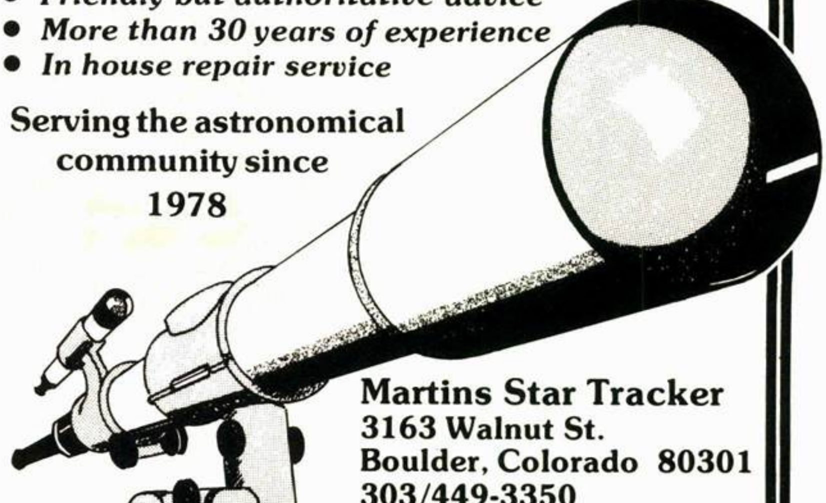

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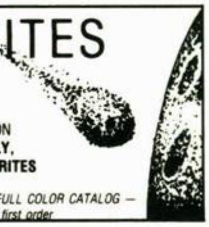

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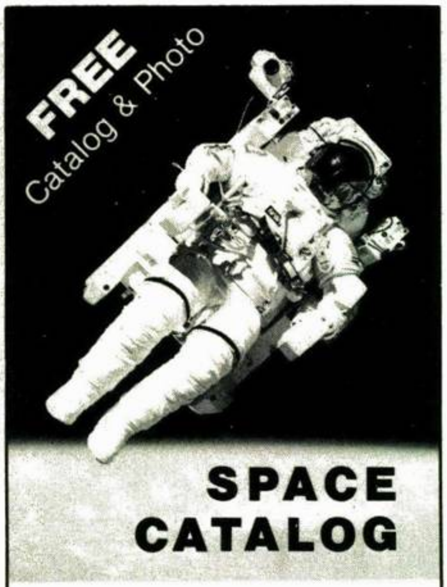

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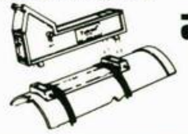

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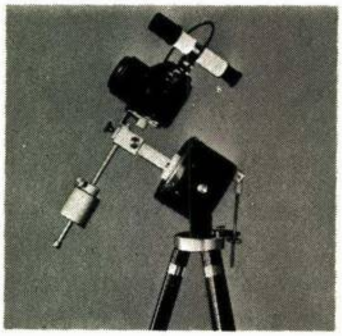

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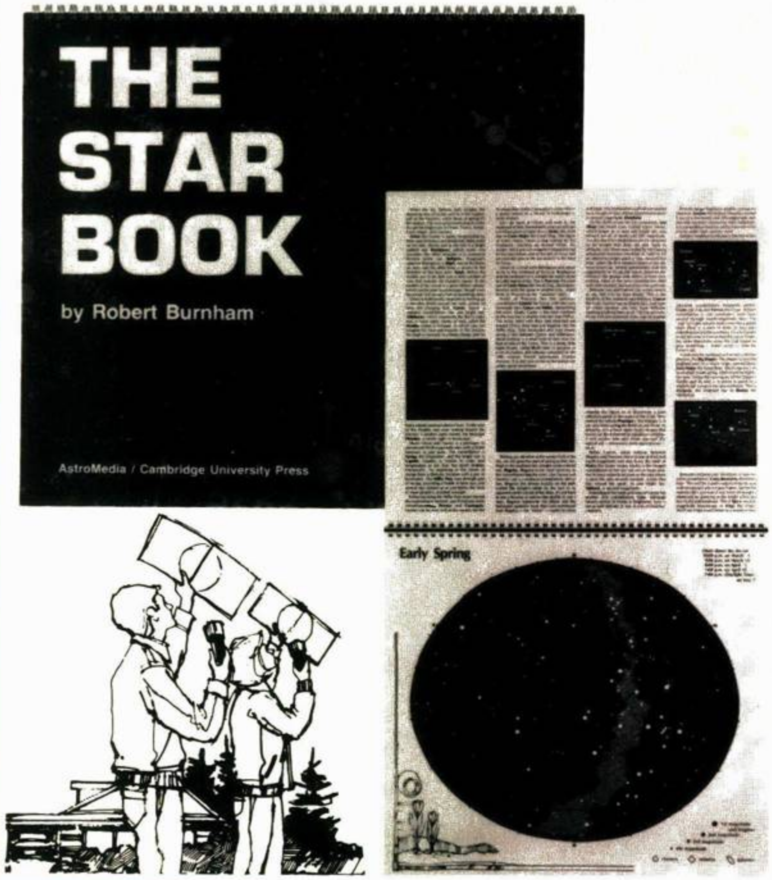

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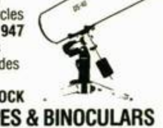

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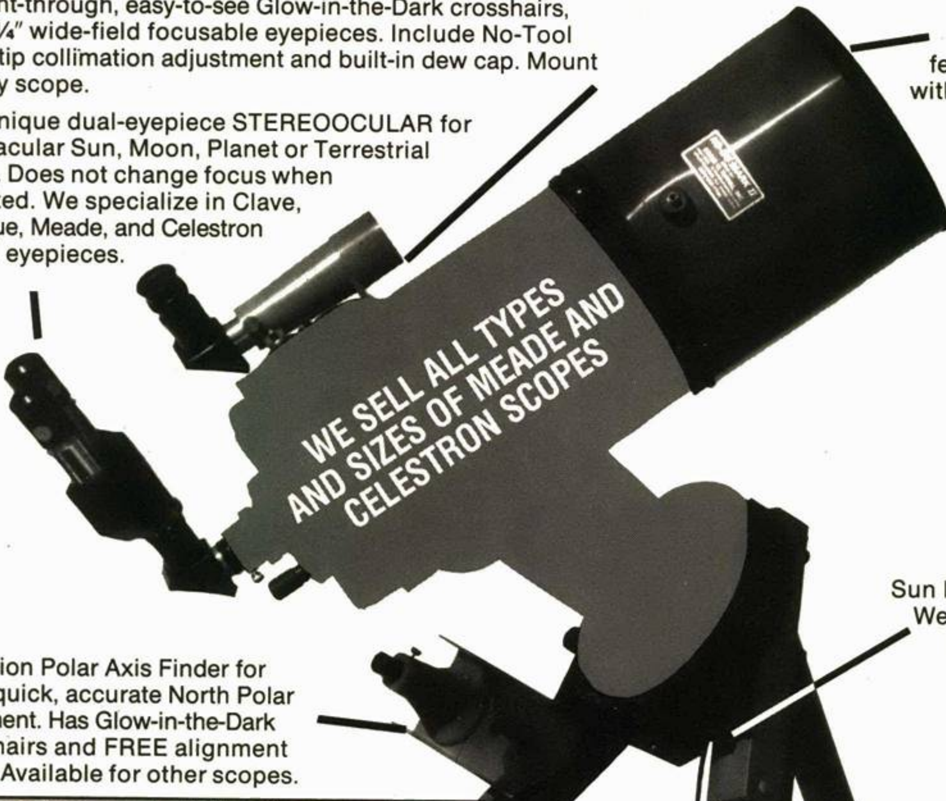

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LUMICON FOR HIGH PERFORMANCE

ASTROPHOTO OF THE MONTH

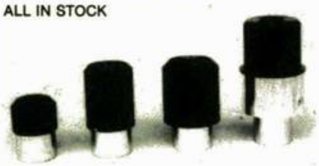
The "Flame Nebula" NGC 2024 in Orion. Also known as the "Christmas Tree" or the "Tank Trucks" nebula. NGC 2024 is seen best usually with either a LUMICON DEEP-SKY or UHC filter. Photo by Don N. Reiners, 16" f/5, 40 min. using hypered 2415 film and a LUMICON 2" EASY-GUIDER.

20mm NAGLER

New 2" eyepiece with 82° field $340

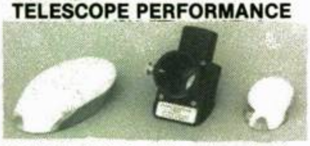
TELE VUE™ EYEPIECES USE THE BEST!!

ALL IN STOCK



Renaissance 4" f/5.5. Telescope	$1395
7.4, 10.4, 13, 17, 21, 26mm Plossl, 50°	$95
1.8X or 2.5X Tele Vue Barlow Lens	$95
32mm Plossl, widest true field in 1¼"	$110
55mm 2" Plossl, widest possible field	$190
15mm Wide-Field, 1¼" eyepiece, 65°	$130
19mm Wide-Field, 1¼" eyepiece, 85°	$145
24mm Wide-Field, "superb," 65°	$160
32mm Wide-Field, 2" eyepiece, 65°	$230
40mm Wide-Field, "awesome," 65°	$295
4.8mm Nagler, 82° field	$150
7mm Nagler, 1¼" eyepiece, 82° field	$185
9mm Nagler, 82° field, "the best"	$225
11mm Nagler, 82° field, 1¼" or 2"	$240
13mm Nagler, 82° field, 1¼" or 2"	$250
20mm Nagler, 82° field, 2" eyepiece	$340

NEW! ENHANCED SILVER DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE



LUMICON 1.3" & 2.1" enhanced silver diagonal mirrors & 1¼" star diagonal.
The new LUMICON diagonal mirrors have a special enhanced silver coating with a protective overcoating for long life. Visible reflectivity is 98-99% compared to 86-89% for standard aluminum coated mirrors. The extra 10-12% transmission is like adding an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32" **$29.95** 1.52" **$34.50** 1.83" **$39.50**
2.14" **$49.50** 2.60" **$65.00** 3.10" **$89.50**
4.25" **$149.50**

ENHANCED SILVER STAR DIAGONAL

90° star diagonals with above enhanced silver mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

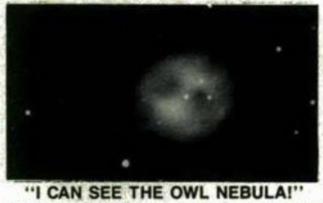
1¼" (1.32" mirror)	**$89.50**
2" (1.83" mirror)(see photo above)	**$145.00**

LUMICON FILTERS STOP LIGHT POLLUTION

UHC Filter™

ULTRA HIGH CONTRAST

The **LUMICON UHC FILTER** is specially designed for visual astronomy in areas of severe light pollution or for viewing very faint nebulae at any location. **UHC** stands for **U**ltra **H**igh **C**ontrast and this filter is guaranteed to yield a higher visual contrast on planetary and emission nebulae than any other filter at any price. 24nm visible bandpass, 482-506nm. Transmission = 85-95%.



"I CAN SEE THE OWL NEBULA!"
Tom Kramer saw the Owl Nebula, M-97, for the first time using a LUMICON UHC Filter. He stated, *"I had never seen M-97. . . I attached the UHC Filter and tried again. M-97 was right there. I could not believe it! The UHC Filter should be standard equipment."* **Tom Kramer, Sayville, NY**

For optimum astronomy, use either the **LUMICON DEEP-SKY Filter** or the **LUMICON UHC Filter**

DEEP-SKY FILTER™

The **LUMICON DEEP-SKY FILTER** improves your view of **all** deep-sky objects including galaxies and comets. It removes natural and man-made light pollution and yields 3-6x contrast gain for nebulae and 1-3x contrast gain for clusters and galaxies. It is ideal for **both** visual use and B&W or color photography. This gentle filter yields the most natural view of any LPR filter available today. 90nm visible bandpass. 442-532nm. H-Alpha 656nm transmission = 85-95%. Visible transmission = 90-95%.

	Standard	**Premium***
0.96" LUMICON DEEP-SKY Filter threads into most 0.96" eyepieces		**$59.50**
1¼" LUMICON DEEP-SKY Filter threads into most 1¼" eyepieces		**$79.50**
48mm LUMICON DEEP-SKY Filter (1.75" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS		**$119.50**
2" LUMICON DEEP-SKY Filter (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography	**$99.50**	**$119.50**
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $8)		**$299.50**
1¼" LUMICON UHC Filter threads into most 1¼" eyepieces	**$79.50**	**$99.50**
48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces	**$159.50**	**$199.50**
Set of Both 1¼" **DEEP-SKY** and **UHC Filters** (Save 11%)		**$159.50**
LUMICON H-BETA Line Filter (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae.	**1¼" $89.50**	**48mm $189.50**
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm 0-III lines	**1¼" $99.50,**	**48mm $199.50**
Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm		**$6.95**
Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece		**$16.00**
Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece		**$20.00**

**Premium filters are selected best of the lot and typically have 5-10% higher transmission. Not always available. Include individually measured transmission data.*

Upgrade to 48mm filters! All are multicoated

UV, Green, Yellow, Orange, Red	**$18 each**
48mm H-Alpha Pass (640nm cut-off)	**$35**
48mm Minus Violet (420nm cut-off)	**$29**
48mm High perform blue, 90% trans	**$35**
Central Star Filter (blue tri-color) 340-470nm bandpass	**$35**
UV-370 U-Band, 320-420nm bandpass	**$35**
48mm Polarizer (2 make variable density)	**$18**
Set 9 ea. 48mm filters ($259 list)	**$195**
2"/1¼" adapter threaded for 48mm filters	**$20**

H-ALPHA PASS FILTER

Yields spectacular contrast gains in B&W photography with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the Minus Violet (MV) Filter.

Specify Lens Size	**H-Alpha**	**(MV)**
46, 48, 49mm	**$35.00**	**$29.00**
52, 55, 58, 62mm	**$45.00**	**$35.00**
67, 72, 77mm	**$52.00**	**$45.00**
82mm	**$55.00**	

Hypered 2415 film, 36 exp . . . **$10.95** . . . **3/$29**

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DEEP-SKY ASTROPHOTOGRAPHY

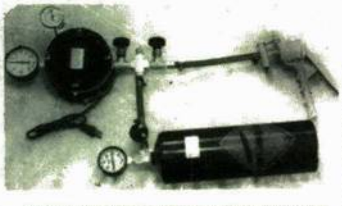
FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15X film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

U.S. Patent 4,473,636

MAKE YOUR OWN HYPERED FILM

MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds **$295.00**



MODEL 600 HYPER-KIT [See Photo] Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates **$350.00**

MODEL 1200 HYPER-KIT is for 4X5" plates and film up to 5X7". Has 2 gas cylinders and includes temperature controller . . **$595.00**

Temperature controller for any HYPER-KIT **$59.50**

Electric Vacuum Pump, Model R-10 **$280.00**

GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X eaiser guide-star selection, use 48mm filters, 360° camera rotation, large prisms fo bright guide-starts. *Specify Camera and Telescope type.*
U.S. Patent # 4,448,500

NEWTONIAN EASY-GUIDER™

Full aperature. Installs in secs. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER	**$169.50**
3X Relay Diagonal (see photo)	**$79.50**
Illuminated reticle eyepiece system	**$89.50**

Guider for Hasselblad **$350,** Mamiya 645 **$199**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Dynamax-8. Includes 50mm achromatic lens for f/5.8 operation-3X shorter exposures! **Superb rich field viewing, too!**

CASSEGRAIN EASY-GUIDER **$225.00**
Adapter for Hasselblad **$185,** Mamiya 645 **$159**

GIANT EASY-GUIDER™

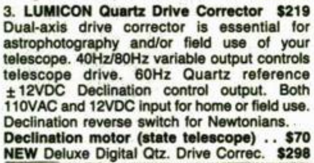
For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER **$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20) . . . . . . **add $99.95**
Adapter for Hasselblad **$195,** Mamiya 645 **$96**

WHAT DO YOU NEED?

1. Illuminated reticle eyepiece **$89**
Lumicon 12mm eyepiece system has adjustable L.E.D. illumination, dual crosslines, battery pack.
2. Cable release for long exposures . **$9.95**

3. **LUMICON Quartz Drive Corrector $219**
Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 40Hz/80Hz variable output controls telescope drive. 60Hz Quartz reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Declination reverse switch for Newtonians.
Declination motor (state telescope) . . $70
NEW Deluxe Digital Qtz. Drive Correc. **$298**



HYPERSENSITIZED FILM

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.).

Film Type, 35mm	**Exposures**	**Price**
2415, Ultra-fine B&W, red sens.	36	**$10.95**
SR1600, fastest of all, color neg	24	**$12.95**
Konica SR200, fine grain color neg	12	**$9.95**
3M 1000, fastest slide film	20	**$12.95**
Fujichrome RD100, fine grain slide	24	**$12.95**
5072, color slides from neg	36	**$6.95**
D-19 B&W Developer	1 gal.	**$6.95**

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Meade® TELESCOPES AT LUMICON

MEADE 2080/LX3 w/MCSO $1685

#712 Dew shield (8") and accessory tray ($140 list) **add $89**

MEADE 2120/LX3 w/MCSO $2590

Accessory shelf for field tripod ($40 list)	**$32**
#710 dew shield (10") Essential! ($140 list)	**$98**
#36 dual-axis drive corrector control box ($150 list)	**$99**
#38 declination motor and clutch ($150 list)	**$99**
LUMICON Giant EASY-GUIDER/Rich-Field viewer for f/4-f/10 operation (state camera)	**$395**

2080/LX3
$1685
2080/LX3
W/MCSO

NEW! Quartz Drive Meade 2080/LX3

The Meade 2080/LX3 with built-in quartz electronic drive system is positively the highest performance 8" Schmidt-Cassegrain telescope system available today.

2120/LX3 10'' System w/MCSO $2590

The 10" Meade 2120/LX3 collects 56% more light than an 8" telescope for significantly improved viewing and astrophotography. It has all the features of the 2080/LX3 (see Meade ads in this magazine for full list of features.)

4'' MEADE 2045 w/table tripod $649

NEW! Meade 2045/LX3 w/quartz drive **$849**

IN STOCK!
NEW!
2045/LX3

Meade Model 2045 — Advanced engineering and superb optical performance in a beautiful ultraportable system.

FEATURES OF THE MEADE 2045

- ★ 4" f/10 Schmidt-Cassegrain optics, F=1000mm
- ★ Motor drive for automatic tracking, 110 VAC input
- ★ **LX3:** quartz-controlled elec. drive, 12VDC or 110VAC input
- ★ High transmission coatings on front corrector lens
- ★ Table tripod for easy polar alignment
- ★ 5X24 finderscope & 1¼" right-angle star diagonal
- ★ 1¼" 25mm (40X) and 9mm (111X) eyepieces
- ★ Fork mount with setting circles, manual slow motion

HIGHLY RECOMMENDED OPTIONS

Model 43 drive corrector uses 12VDC ($130 list)	**$99**
See Meade 2080/LX3 options	
Wedge & field tripod for Meade 2045 ($380 list)	**$298**
Dew shield ($80 list) .. **$55** Solar Filter ($180)	**$139**

TELESCOPE SALE

Meade
THE LEADER'S EDGE
Authorized Meade Dealer
ONLY
$698!

Meade Model 628 6" f/8 **w/motor**, 1¼" focuser, 6X30mm finder ($1226 list)	**$698**
Meade Model 628C 6" f/8 **w/motor**, 2" focuser, 8X50mm finder ($1500 list)	**$798**
Celestron-11 with Starbright coatings	**$3250**
Celestron Super Polaris SP-C8, 8" f/10 on equatorial mount w/high transmission coatings ($1950 list)	**$1095**
Celestron CO-114, 4½" f/9 reflector & mount	**$425**
Meade Model 310, 80mm f/11 refractor ($950 list)	**$449**
Meade Model 107-D 4" f/10 spotting scope	**$429**

NEW! 2080/GEM and 2120/GEM

Schmidt-Cassegrain Optics on German Equatorial Mount

2080/GEM, 8" f/10 w/equatorial mount ($2150 list)	**$995**
Multi-coated silvered optics, boost transmission 18%	**add $149**
2120/GEM, 10" f/10 w/equatorial mount **and with multi-coated silvered optics** ($4400 list)	**$2195**
Dew shield & accessory tray, 8" .... **$72** 10"	**$144**
#785 motor and quartz drive correc. system ($310 list)	**$198**
#3000 computer control system ($1500 list)	**add $949**

The Meade 2080/GEM and 2120/GEM telescopes include the same diffraction limited optics as the 2080/2120/LX3. Large, stable German equatorial mount with setting circles, slow motion controls on both axes, large 8X50mm finderscope, 25mm 1¼" eyepiece, integrated polar alignment scope, and heavy duty adjustable height tripod (hardwood for 2080, metal for 2120). The computer control provides automatic object location from an extensive software library of deep-sky objects.

OPTIONS BOOST PERFORMANCE

LUMICON UHC Filter for nebulae. Standard 1¼"	**$79**
Prem 1¼", **$99;** Std 48mm, **$159.50;** Prem 48mm,	**$199.50**
LUMICON Deep-Sky Filter, 1¼" Premium	**$79**
48mm Prem Deep-Sky ..... **$119.50, $99.95** w/Easy-Guider	
Adapter for viewing w/1¼" eyepiece	**$20**
Dust covers. Keep optics clean. For 6"	**$16/pair**
8" .... **$20/pair;** 10" .... **$18;** 16"	**$24**
LUMICON Rich-Field Viewer (2080)	**$140**
LUMICON Newtonian Easy-Guider, 1¼" or 2"	**$169**
#122 2X Barlow ($70 list)	**$56**
Dual-axis drive corr. and elec. dec. for 2080/LX3	**$198**
for model 628, 826, DS-10 .... **$340** for DS-16	**$440**
Tele Vue 32mm Plossl 1¼" eyepiece	**add $99**
LUMICON Cassegrain EASY-GUIDER for Meade 2045, 2080/LX3 and 2080/GEM (state camera)	**$225**
Illuminated reticle eyepiece & battery pack	**$89.00**

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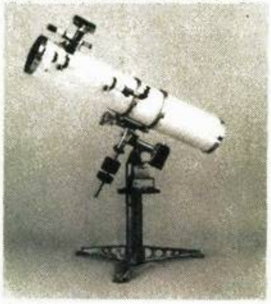
All telescopes shipped F.O.B. Livermore

8'' f/6 NEWTONIAN.........$995

SALE

$698
(Model 628)

$798
(Model 628C)
6'' f/8 with
motor drive



Model 826, 8'' f/6 Telescope w/accessories

Model 628, 6" f/8 with motor drive ($1220 list)	**$698**
Model 628C, 628 w/2" focuser, 8x50mm finder ($1500)	**$798**
Model 826C, 8" f/6 with motor drive, #680 2" focuser and 8x50mm finderscope ($1640 list)	**$995**

—Collects 78% more light than a 6" telescope.

These Meade Deluxe Series reflecting Telescopes have superb image quality at low or high power. They include an equatorial mount with motor drive, pier, legs, setting circles, 2" rack & pinion focuser, 8X50 finderscope (628C & 826C only), 25mm (48X) and 9mm (135X) 1¼" eyepieces, altitude and azimuth fine adjustments for polar alignment.

#43 drive corrector uses 12VDC ($130 list)	**$99**
#47M Dual-axis drive corrector & elec. dec.	**$340**
1¼" or 2" EASY-GUIDER (state camera)	**$169**

6'' f/5 NEWTONIAN........$695

IN STOCK!

STILL
AVAILABLE
AT 1985
PRICES!

Models 6600 (6" f/5) & **8800** (8" f/4.5) telescopes

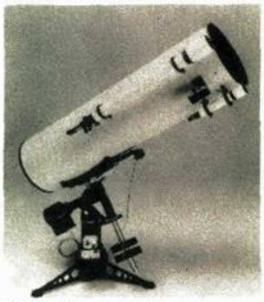
Model 6600, 6" f/5 Newtonian telescopes ($1400 list)	**$695**
—Best performance & value; bright, wide views.	
Model 8800, 8" f/4.5 Newtonian Telescopes ($1800)	**$895**
—Collects 78% more light than a 6" telescope.	

These Meade Professional Series reflecting telescopes yield superb rich-field viewing w/bright images. They include an equatorial mount w/adjustable tripod, setting circles, slow motion controls, 6x30mm view-finder, 1¼" focuser, 25mm & 9mm 1¼" eyepieces & accessory tray.

#784 motor & quartz drive corrector ($310 list)	**$219**
Basic camera adapter (for moon & planets)	**$32**
1¼" LUMICON Easy-Guider (state camera)	**$169**

16'' f/4.5 NEWTONIAN......$1995

STILL
AVAILABLE
AT 1985
PRICES!



Meade DS-16A with Accessories

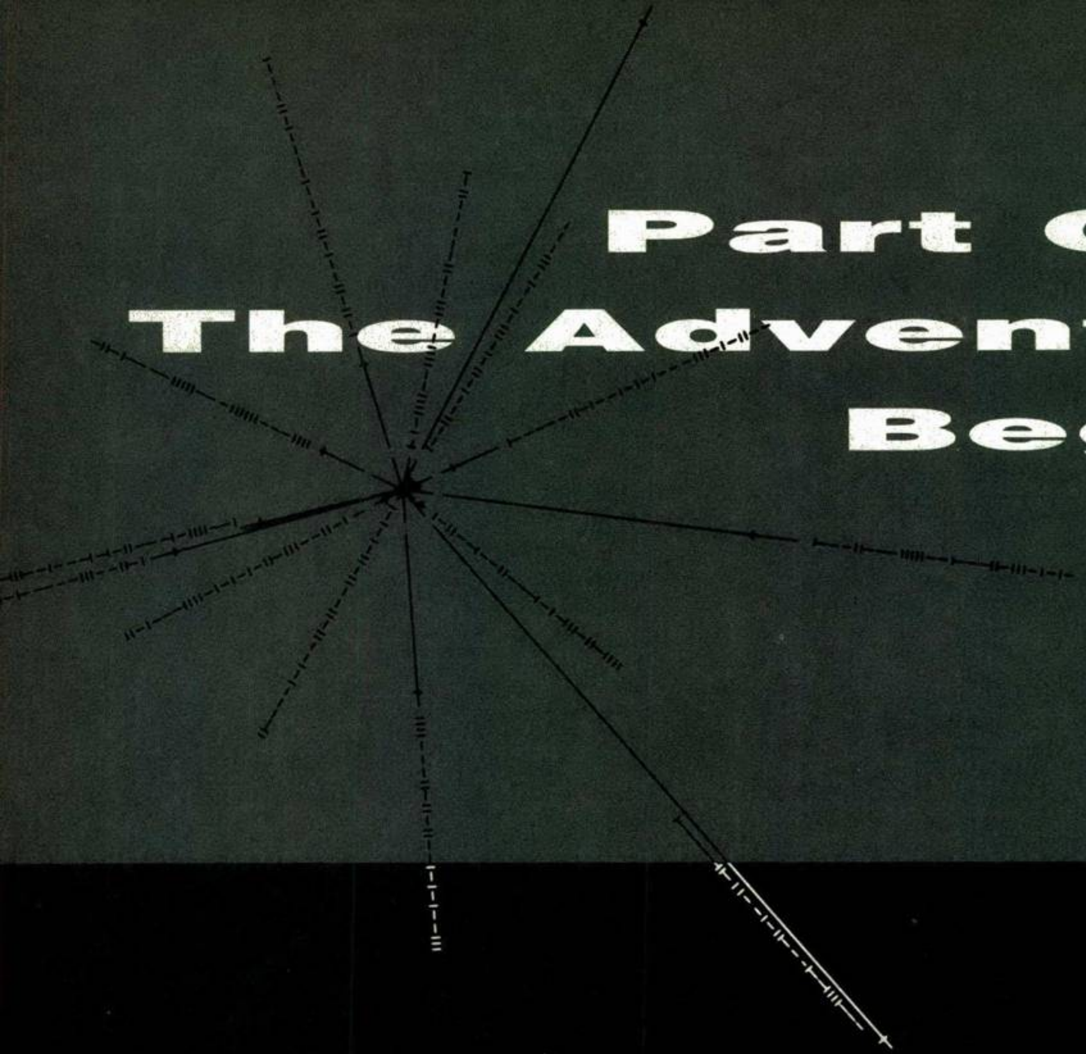
The DS Series of 10" and 16" reflecting telescopes are ideal for deep-sky viewing and photography.

DS-10A, 10" f/4.5 with motor drive ($1600 list)	**$995**
—Gathers 56% more light than an 8" telescope	
DS-16A, 16" f/4.5 with motor drive ($3140 list)	**$1995**
Sealmaster ball bearings, highly recommended	**add $229**
—Gathers 400% more light than an 8" telescope	

Both the DS-10A and DS-16A telescopes include an equatorial mount, #680 2" focuser, motor drive, setting circles and 25mm 1¼" eyepieces. The DS-10A is shipped freight collect.

6x30mm finderscope with brackets ($56 list)	**$42**
8x50mm finderscope with brackets ($130 list)	**$96**

Part One: The Adventure Begins



June 13, 1983, is not a date stamped indelibly on everyone's memory, but perhaps it deserves to be. On that date the first artifact from Earth — a small spacecraft called Pioneer 10 — crossed the orbit of the outermost planet and began its journey to the stars.

We shall never know the fate of Pioneer 10. Perhaps after millions of years it will drift into the realm of another sun and blindly encounter a new family of planets. Perhaps it will sail unscathed through the vast atmosphere of a red supergiant only to be wrecked by the gravitational pull of an orbiting black hole. Or perhaps it will roam the Galaxy forever, its tiny metal body surviving while the last of the stars burns out.

Yet Pioneer 10 is not alone in its interstellar wanderings. Already it has been joined by three other terrestrial probes heading for the stars — Pioneer 11, Voyager 1, and Voyager 2. They are primitive vehicles that are slow and unequipped for such long trips. And their chances of ever reaching another world — let alone an alien intelligence — are incredibly slim. But that they are star-bound at all is extraordinary. They will be the first craft to leave the solar system — the first explorers from our world to enter the vast wilderness beyond the Sun's domain.

These four craft are blind and deaf probes, cosmic messengers only because plaques fixed to them carry simple information about Earth and its inhabitants. They offer a slow, poor *man's version* of interstellar travel. The next step in the progression of spaceflight naturally would be a far more ambitious and expensive proposition — sending man to the stars. But these key questions remain: Can high-speed interstellar travel for human beings really be achieved? What does it involve? What physical and technological barriers must be surmounted? In trying to answer these questions we shall inevitably stray into that twilight land between science fact and science fiction. We shall extrapolate and speculate, peering to the limits of what may be possible.

But we start on firm ground, with the territory close at hand and with those four remarkable space probes already leaving their home star far behind.

Toward the Heliopause

The first of the Jupiter probes, Pioneer 10, was launched in March 1972. Twenty-one months later the craft sent back streams of data as it passed the giant planet at a distance of 131,000 kilometers. Then Pioneer 10 continued on its journey out of the solar system, crossing the orbit of Neptune — 4.5 billion kilometers from the Sun — on that historic day in June 1983.

Pioneer 10's sister craft, Pioneer 11, set out in April 1973 and rendezvoused with Jupiter in December 1974. Pursuing a different course, Pioneer 11 passed within just 43,000 kilometers of Jupiter's cloud tops and received a gravitational assist from the giant planet, which slung the craft toward Saturn.

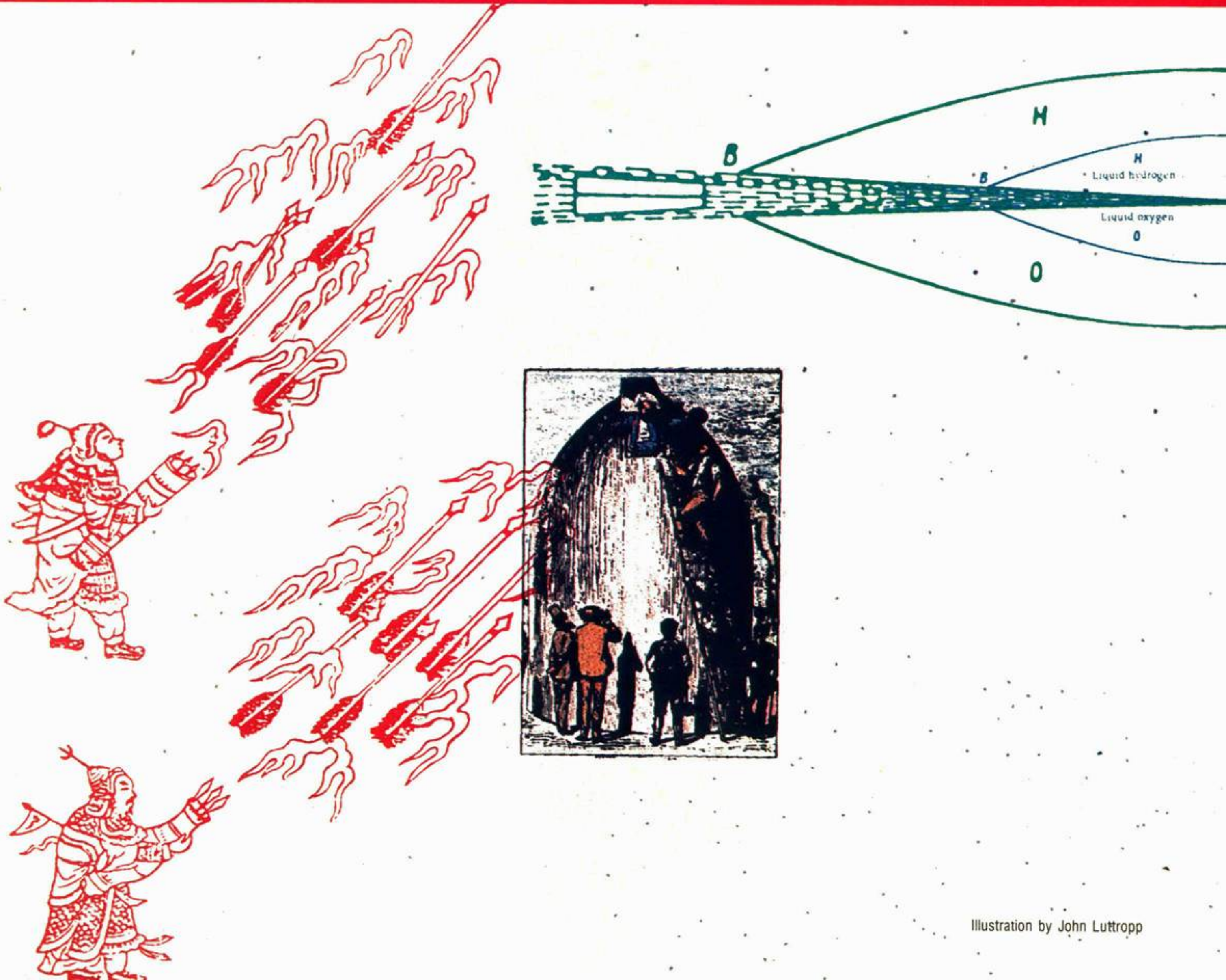
Then followed the more sophisticated twin Voyagers. Launched in August 1977 (Voyager 2) and September 1977 (Voyager 1), each of these craft entered Jupiter's gravity field and, with increased speed, flew on to Saturn. There, at the ringed world, Voyager 1 ended its planetary pinball game and headed into deep space. Voyager 2, though, has continued on to Uranus and is now bound for an encounter with Neptune in 1989.

As the first explorers of the mysterious gas giants, these four robot craft could not have been more successful. But what will they encounter as they depart from the familiar worlds of the solar system and confront the awesome chasms that lie beyond?

First, we must differentiate between interplanetary space and interstellar space. Does the outermost limit of the Sun's gravitational influence mark the boundary of the interstellar void? If so, the Oort Cloud, presumably a storehouse of ancient cometary nuclei, could be our last staging post en route to the stars, at roughly 50,000 astronomical units (AU) or 7.5 trillion kilometers from the Sun.

STAR TREK

BY DAVID DARLING


H
B
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Liquid hydrogen
Liquid oxygen
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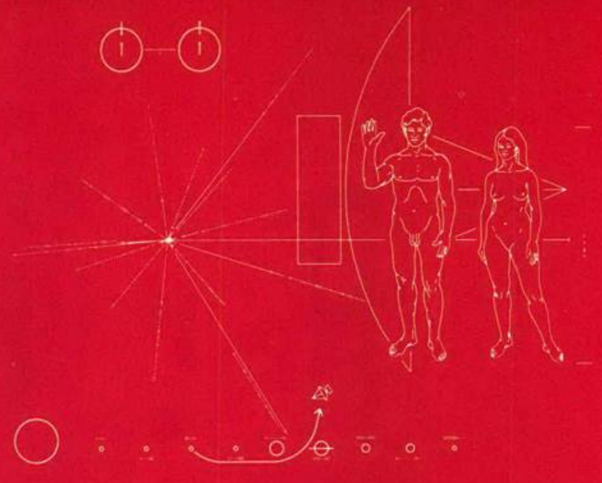
O

Illustration by John Luttropp



"We shall never know the fate of Pioneer 10. Perhaps after millions of years it will drift into the realm of another sun and blindly encounter a new family of planets. Perhaps it will sail unscathed through the vast atmosphere of a red supergiant only to be wrecked by the gravitational pull of an orbiting black hole. Or perhaps it will roam the Galaxy forever, its tiny metal body surviving while the last of the stars burns out."

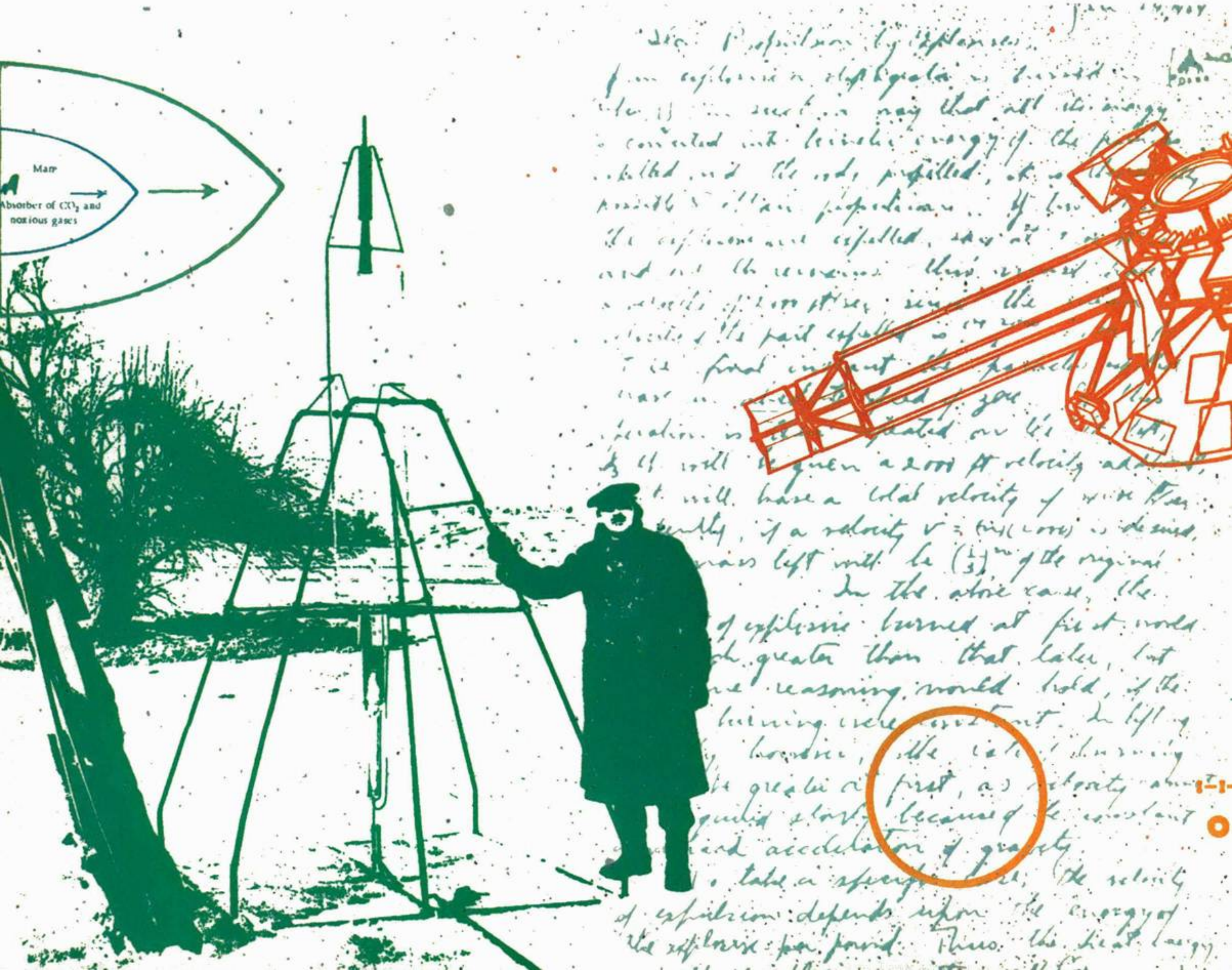
This is not the end of the Sun's gravity domain, however. Recent computer simulations have shown the Sun is capable of tethering objects out to a distance of between 80,000 AU and 100,000 AU, or about 0.5 parsec. This distance is about one-third of the way to the nearest star.

Yet gravity is a force that falls off gradually and never ends. A more meaningful definition of the precise boundary of the solar system might come from examining the behavior of the solar wind, the outflow of charged particles from the Sun.

At some point, the solar wind must be halted by the pressure of gas in the interstellar space beyond. As a result, there must be a surface — the heliopause — where the particles of the solar wind pile up at a shock front as they collide with the interstellar gas. In theory, this collision will emit low-frequency radio waves that the Pioneer and Voyager spacecraft could detect.

The heliopause should not be perfectly round: it should be stretched out into a pear shape by the interstellar gases flowing around it. Pioneer 10, as it happens, is traveling along the tail of the heliopause and may not reach the boundary before its power supply runs out around 1995. At present it is roughly 37 AU away and sending back data that suggests the heliopause must lie at least 65 AU from the Sun.

But the message from the Voyagers is different. They have already begun to pick up faint radio signals, peaking at around 2 kilohertz to 3 kilohertz, that may be coming from the heliopause boundary. Just possibly, these signals could have a completely different origin — a galactic radio source, for instance,


Man
Absorber of CO_2 and noxious gases
will have a total velocity of
if a velocity v = ... is desired,
mass left will be $(\frac{1}{3})^n$ of the original
In the above case, the
of explosive burned at first would
greater than that later, but
reasoning would hold, if the
burning were constant.
first, as velocity
because of the constant
acceleration of gravity.
take a specific case, the velocity
of expulsion depends upon the energy of
the explosive per pound. Thus the heat energy

of a type never before encountered. But the signals are growing stronger as the Voyagers move outward, and that is just what we should expect if the heliopause is responsible.

Assuming the density of the solar wind falls off uniformly with distance, the Voyager signals suggest the heliopause lies some 46 AU from the Sun in the direction the Voyagers are moving. If this analysis is correct, the first craft to reach the heliopause boundary and cross into interstellar space will not be the most distant, Pioneer 10. Instead it will be Voyager 1 as it heads "upward" at a steep angle out of the plane of the solar system less than six years from now.

Finding the heliopause would be a great breakthrough, but will any of the four spacecraft approaching it survive that long without shutting down completely? The answer critically depends on the lifespan of the crafts' radioisotope thermoelectric generators (RTGs). Powered by the steady decay of plutonium-238, the RTGs on the Pioneers are expected to last until the mid-1990s, and those on the Voyagers until between 2012 and 2019. By 2012 both Voyagers will be over 100 AU out — and most likely will have passed through the heliopause.

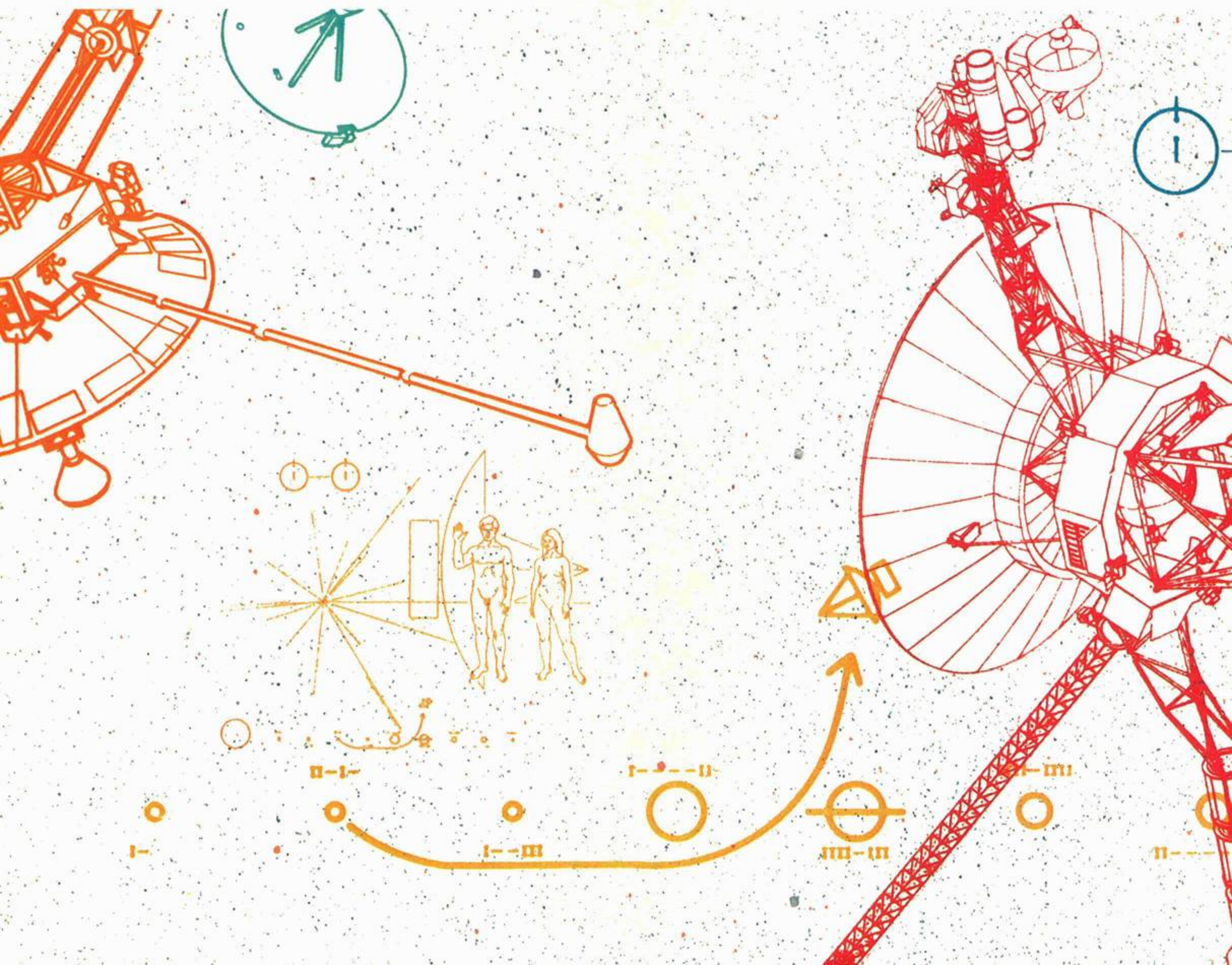
Bound for the Stars

And then where will these spacecraft venture? In 1984 a group of engineers from the Jet Propulsion Laboratory published a paper titled "Prospects for the Voyager Extra-Planetary and Interstellar Mission." In the report they charted the far-future courses of the Pioneer and Voyager spacecraft among the nearby stars, taking into account the vital fact that the stars themselves are moving.

Pioneer 10 has a 32,600-year-long trek ahead of it before it makes even a remote flyby of any star. Then it will pass 1.0 parsec from the M-type red dwarf Ross 248, presently 3.2 parsecs away but closing to less than 1 parsec from Earth by 34,000 A.D. An intelligent spacefaring "Rossian" who happened to spot Pioneer 10 might be intrigued by the plaque it bears showing a figure of a man and woman in front of an outline of the spacecraft. Perhaps less amusing to them would be the other details showing Pioneer's point of origin — a bright star clearly visible in their night sky and only a cosmic stone's throw away.

As an aside, it is interesting to note that as Pioneer 10 moves away from us — with a speed of 46,000 kilometers per hour — it is sending back signals with the strength of just eight watts. These signals now travel for over five hours to reach us and the beam is spread out over an area almost as large as the orbit of Venus. The energy collected by a 64-meter-wide dish of NASA's Deep Space Tracking Network is only one million-trillionth of one watt. Stated another way, if that much energy were collected and stored over the next 100 million years, it would be just enough to light a single Christmas tree bulb for one thousandth of one second! And Pioneer 10's signal will grow weaker as it travels farther out.

Pioneer 11 has a somewhat longer trip before it passes 0.5 parsec from another nearby M-type dwarf, AC +79° 3888, in the year 44,400 A.D. By then the spacecraft will be 0.9 parsec from home. Two-and-one-half millennia earlier, Voyager 1 will



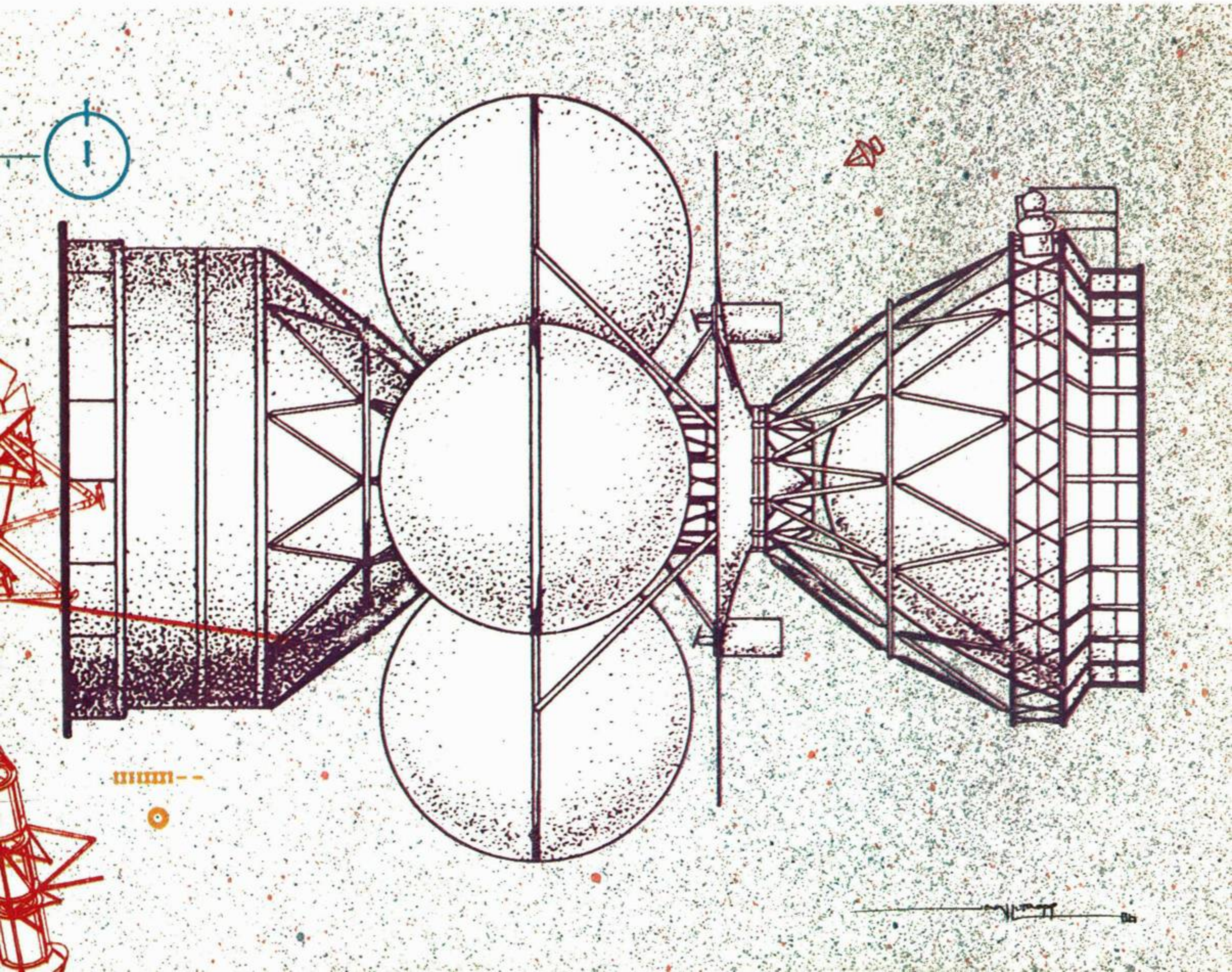
"The Daedalus mission is remarkable: to reach Barnard's Star — a red dwarf 1.8 parsecs away — within a human lifetime, explore the star system, and report back to Earth. Deploying its onboard telescopes and sending small robot probes on sorties to any interesting worlds it finds, Daedalus gathers a wealth of data on Barnard's Star system. It analyzes the mass of data using a central computer programmed with all the knowledge, foresight, and artificial intelligence its human creators could muster. Then, still hurtling on at one-eighth light-speed (Daedalus has no brakes!), it transmits its refined, processed observations back to Earth. Roughly fifty-six years after seeing its main engine blaze into life, mission controllers on Earth — or more likely their children and grandchildren — will see what Daedalus has found."

also rendezvous with this star at about the same distance. Voyager 2 will follow up with a 0.9-parsec flyby of AC +79° 3888, 47,000 years from now.

Curiously, Voyager 2 will also come reasonably close to Ross 248 — missing it by less than 0.5 parsec — even though the spacecraft is heading in almost exactly the opposite direction as Pioneer 10 is! The explanation is that Ross 248 itself happens to be moving very fast in relation to the Sun — approaching us presently with a speed of 81 kilometers per second, so it will be only 0.9 parsec away in another 34,900 years.

For Voyager 2, the prospects are perhaps the most exciting. Having flown by Jupiter, Saturn, Uranus, and Neptune, crossed the heliopause, and approached both Ross 248 and AC +79° 3888, the spacecraft will move toward its most spectacular encounter. If the JPL team's computer modeling is right, Voyager 2 will pass — depending on its exact course after leaving Neptune — within 0.2 parsec of the brightest star in the sky, Sirius, in the year 359,900 A.D. By then, however, the Dog Star will have more than doubled its distance from us and will be less of a spectacle in our night sky.

Speculating beyond these predictions is pointless. Possibly, a portion of the remaining fuel in one of the craft will be used to target it more accurately at a nearby star and to bring it within range of a suspected planetary system. But, unless some inquisitive aliens manage to discover — against all odds — Pioneer's gold plaque or Voyager's phonograph record and decipher one of them, our first forays into the interstellar sea will have



accomplished nothing. Within a few decades all four of our original "starships" will be silent and dead.

Where Does This Lead?

The first human artifacts to head toward the stars are "escaped" interplanetary probes. How close, then, are we to building the first true interstellar craft? Alas, we are still far from that. Interstellar travel is not merely an extension of interplanetary travel. (Unless you think a spaceflight to the Moon is just a grander, more refined version of a barefoot stroll around the park.) A dedicated scientific mission to the stars involves qualitative differences from anything that has ever been accomplished before. The reason is the sheer vastness of interstellar space.

Think of the Sun as a ball as wide as the dot over this "i." That gives us a scale on which a tenth of one millimeter equals roughly 800,000 kilometers. On this scale Earth is an exceedingly tiny dot orbiting the Sun less than 2 centimeters out. Neptune, currently farther from the Sun than Pluto, would be 56 centimeters (slightly under 2 feet) away, and farther out still would be Pioneer 10 at 68 centimeters (slightly over 2 feet). On this scale the nearest star, the red dwarf Proxima Centauri, would be a tiny speck 1 kilometer (3,000 feet) in the distance!

In reality, Proxima Centauri lies 1.3 parsecs (40 trillion kilometers) away and is a dim, far-flung member of the Alpha Centauri triple-star system. Alpha Centauri A itself is a Sunlike star with a close companion, Alpha Centauri B, that is somewhat fainter, cooler, and larger than Alpha Centauri A.

Within 4 parsecs we encounter about two dozen more stars, the majority of which are red dwarfs. The brightest of the stars is Sirius A, a hot, white star accompanied by a white dwarf called Sirius B. Only two other stars besides Sirius, Procyon A and Alpha Centauri A, outshine the Sun within this 4-parsec radius.

Nevertheless, there are plenty of interesting stars in our little corner of the Galaxy: dwarfs red and white, flare stars, binaries and triples, normal G-type, F-type, and A-type stars, a few yellow and orange sub-dwarfs not unlike the Sun, and several stars suspected of having planetary companions. This last fact is particularly important, because one of our main goals in venturing into interstellar space will surely be to "seek out new worlds and civilizations" — not simply to improve our knowledge of the stars themselves.

But we come back to that old problem of distance. The fastest any space vehicle has moved to date is 51,800 kilometers per hour, in the case of Pioneer 10. That suits us fine for jaunts to nearby planets, but it is certainly not adequate for star travel. With a final cruising speed of about 40,000 kilometers per hour, Pioneer 10 will take over 78,000 years to cover a single parsec! But can this speed be increased? Using conventional chemical rockets, combined perhaps with a gravity assist from a massive planet like Jupiter, we can easily envisage a tenfold improvement. But that would *still* mean over 10,000 years to voyage to the nearest star. Clearly, speeds that are adequate in the solar system are inadequate for interstellar travel. We need a totally new form of propulsion.

Project Daedalus

Take a trip forward in your imagination to the mid-twenty-first century. You are in Earth orbit, gazing at the slow assembly of a great structure — a giant collection of engine chambers, fuel tanks, lattice-frameworks, and complex instruments. This is the 190-meter-tall Daedalus starship, a robot spaceship designed in the 1970s by scientists of the British Interplanetary Society (see "Daedalus: Design for a Starship," ASTRONOMY, October 1983.)

The Daedalus mission is remarkable: to reach Barnard's Star — a red dwarf 1.8 parsecs away — within a human lifetime, explore the star system, and report back to Earth.

The Daedalus starship would gain the incredible propulsion capability necessary to accomplish this mission from a process already familiar to Earth's departments of defense — nuclear fusion. But here is the hitch: Daedalus will work using deuterium and helium-3 fusion. The latter, a helium isotope, is very rare on our home planet. To gather the 30,000 tons of it needed to power Daedalus, another, richer source must be used, which is located some 800 million kilometers away on the huge, cold, alien "surface" of Jupiter.

Now you cross the asteroid belt to gaze on the swirling Jovian atmosphere and the fantastic mining operation taking place there. Over one hundred unmanned floating factory ships are at work in the turbulent Jovian clouds — drawing in the surrounding gassy brew and sifting out the precious helium-3. Periodically they are visited by manned shuttle craft that carry the helium-3 to a safer "fuel dump" orbiting one of Jupiter's moons.

And so, after two decades of effort and the completion of the most complex engineering project ever attempted, the moment arrives. The Daedalus starship slowly moves to Jupiter for fueling — and its mission to Barnard's Star begins.

The main motor ignites. From now on, two hundred and fifty times every second a small pellet containing frozen deuterium and helium-3 is shot into the giant engine chamber at the back of the ship. Each pellet is met by a fusillade of high-speed electrons — fast enough to trigger explosive fusion reactions between the deuterium and helium-3. Erupting with the force of several tons of TNT, the fusion products rush out from the engine chamber and push Daedalus forward with incredible thrust. The craft's engines do not stop after a few minutes of frantic effort: they burn continuously for more than two years, accelerating the starship up to 7 percent of the speed of light, or 21,000 kilometers per second. (Compare that to Pioneer 10's snail-like 40,000 kilometers per *hour*.) Then the first, massive stage of Daedalus drops away and the second stage cuts in, driving the craft up to 12 percent light-speed over the next twenty-one months. Finally, the second stage falls silent and Daedalus coasts on at 36,000 kilometers per second for another forty-seven years. At the end of that period the ship arrives at Barnard's Star and enters the most important phase of its mission.

Deploying its onboard telescopes and sending smaller robot probes on sorties to any interesting worlds it finds, Daedalus gathers a wealth of data on Barnard's Star system. It analyzes the mass of data using a central computer programmed with all the knowledge, foresight, and artificial intelligence its human creators could muster. Then, still hurtling on at one-eighth light-speed (Daedalus has no brakes!), it transmits its refined, processed observations back to Earth. Roughly fifty-six years after seeing its main engine blaze into life, mission controllers on Earth — or more likely their children and grandchildren — will see what Daedalus has found.

Of course, it will never happen exactly like this. Project Daedalus is merely a design, a twentieth-century conception of what a future starship might be like and how it might work, with no more relevance than Leonardo da Vinci's plans for a helicopter. The plan's value lies in simply showing that, using technology not too far from our grasp today, flights to the stars are feasible. With a concerted effort we could at least send robot ships on journeys to the nearest stars lasting less than a human lifetime.

Yet that would only be the first step. Next month we shall look at how interstellar flight might develop in the long term. We shall look at exotic methods of propulsion, at the difficulties of moving beyond the immediate solar neighborhood, and at the prospects for colonizing the stars in the centuries to come.

David Darling is a computer scientist and freelance science writer living in Cumbria, England. His article "Deep Time," an exploration looking trillions of years into the future of the universe, was published in the January 1986 issue. The second part of "Star Trek" will appear in next month's Stellar Frontiers.

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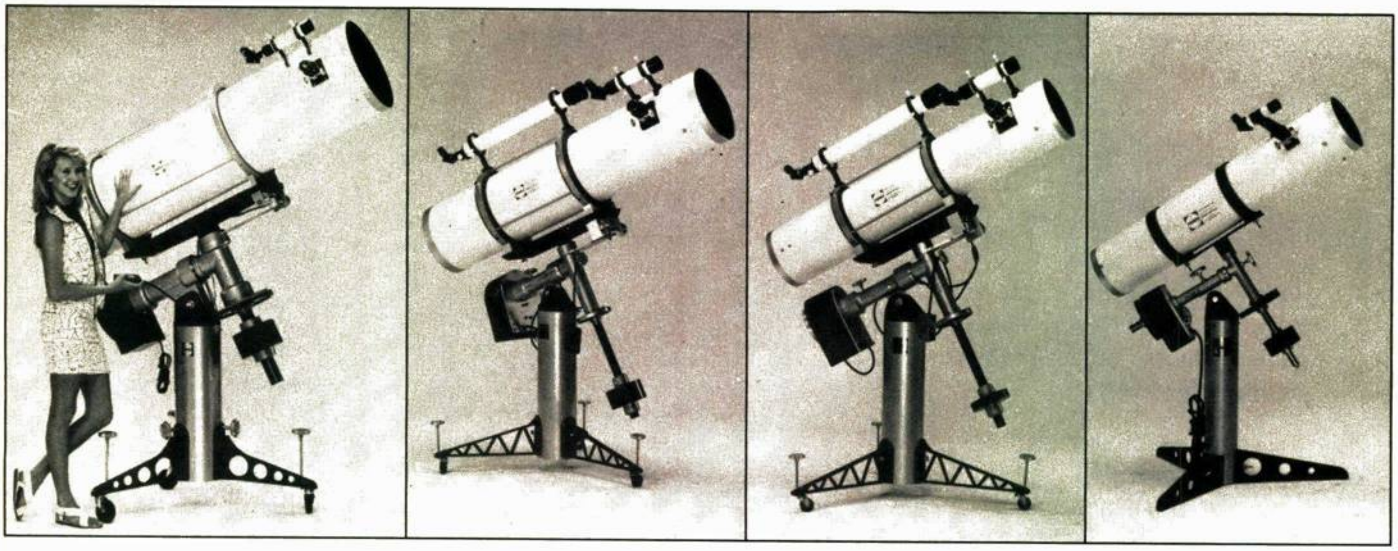

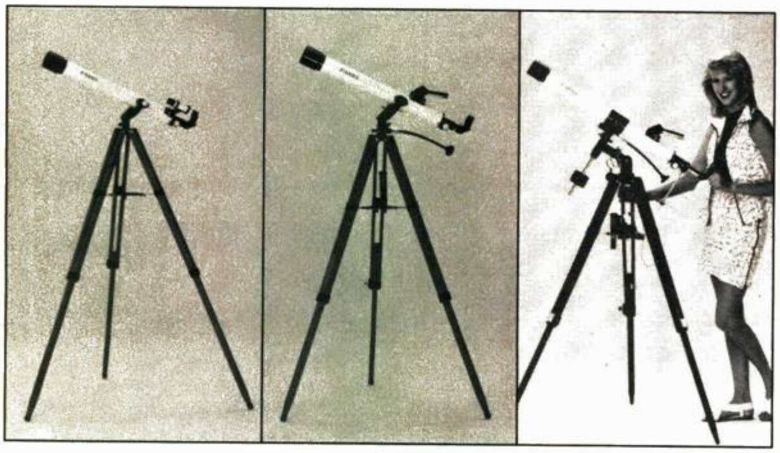

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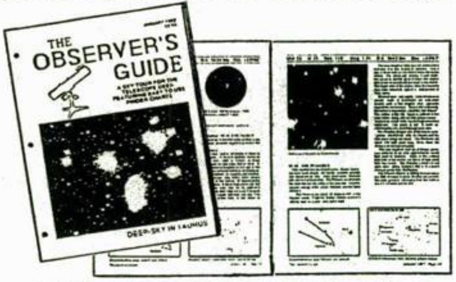

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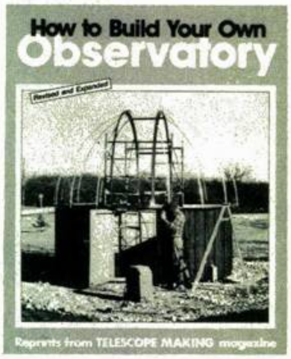

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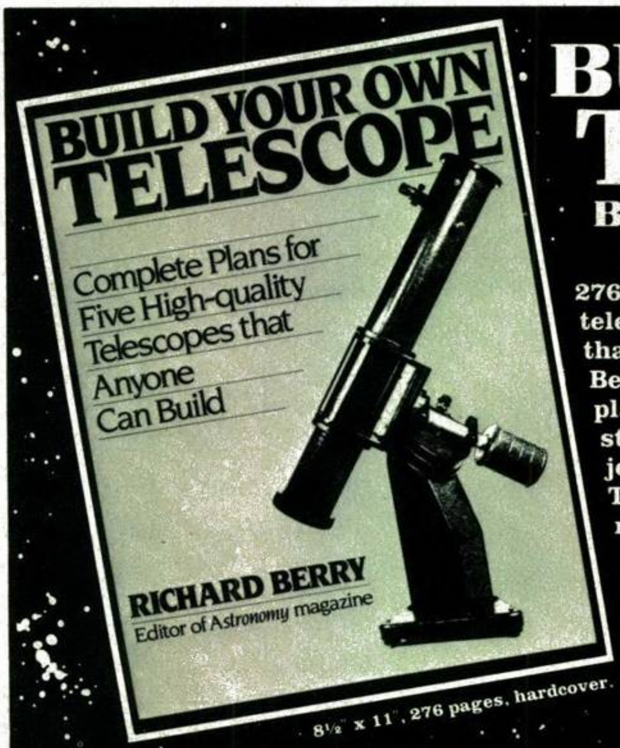
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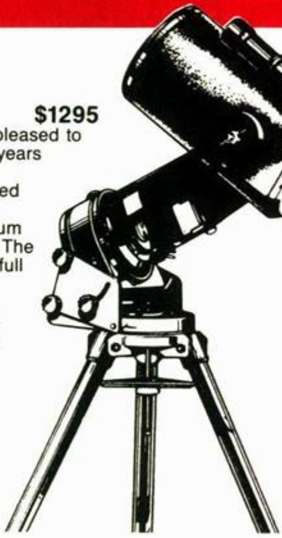

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T to C adapter	$29
Series 6 filter set	$59
Accessory case	$29

Bausch & Lomb 6000 Pro — $899

6" Schmidt-Cassegrain professional model with enhanced optical coating system. Includes electric clock drive, case, 2 eyepieces, lifetime warranty, and more. $1600 list.

Bausch & Lomb 6000 — $849

6" Schmidt-Cassegrain. $1525 list.

Bausch & Lomb 4000 Pro Kit — $539

4000 Pro with Barlow and 35mm camera adapter.

Bausch & Lomb 4000 Pro — $499

4" Schmidt-Cassegrain compact telescope. 1200mm f/11 coated optics, plus aluminum coated primary mirror, silver coated secondary mirror, and multicoated corrector plate. Great for astrophotography and bright viewing. With electric clock drive, case, two eyepieces, table tripod, lifetime warranty, and more. $1010 list.

Bausch & Lomb 4000 Observatory — $449

4" Schmidt-Cassegrain. $950 list.

New Bausch & Lomb RV 5+ Reflector — $679

Newtonian telescope designed for the more advanced amateur astronomer. Features a fast f/5.5, 5.1" optical system, three eyepieces, tripod, accessory tray, equatorial mount with slow motion controls, built-in polar axis finderscope, quartz drive, and more. $1299 list.

New Bausch & Lomb 4.5" Newtonian Reflector — $359

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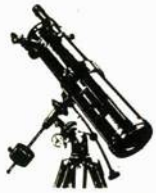

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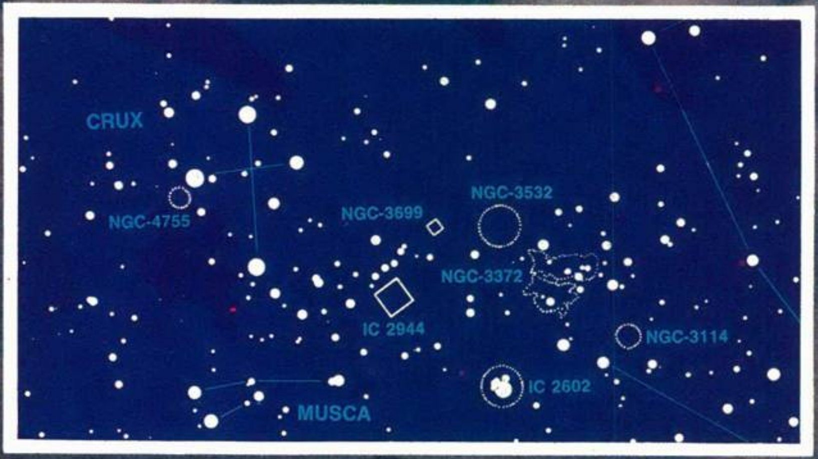

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Top: The Beehive cluster in Cancer (M-44) is one of the brightest clusters and holds fifty stars in an area spanning three Moon diameters. Photo by Lee C. Coombs.

Above: Hydra's star cluster M-48 glows with a collective magnitude of 5.8, just visible as a misty glow to the naked eye on dark nights. Photo by Jack Newton.

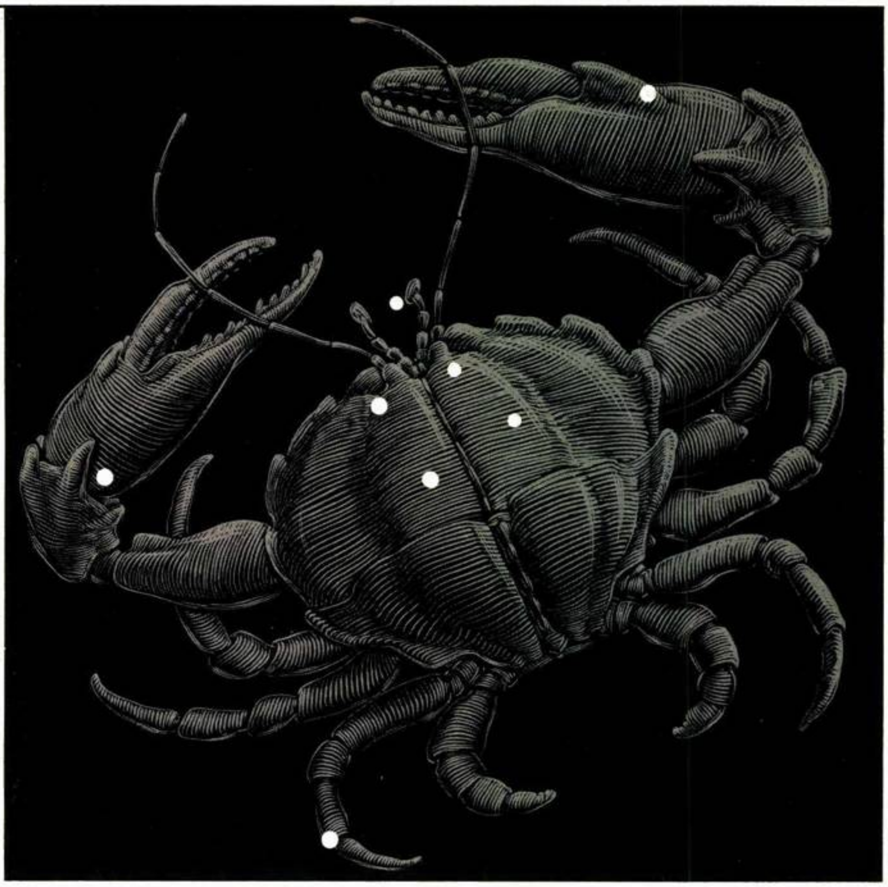
Left: M-67 in southern Cancer contains two hundred faint stars that combine for a 7th-magnitude glow. Photo by Clive Gibbons.

Cancer

Cnc
Cancri

Hydra

Hya
Hydrae



Keith Ward

Bounded by the bright constellations Gemini and Leo to the north, the inconspicuous part of sky containing **Cancer** the Crab and western **Hydra** seems to be almost empty when viewed with the naked eye. Only a sprinkle of faint naked-eye stars and the 3rd-magnitude glow of the Beehive cluster are visible. But view Cancer and western Hydra with a backyard telescope, and you'll discover a region containing several bright, scattered star clusters, two multiple-star systems, and many galaxies.

The brightest deep-sky object in Cancer is the sprawling open cluster **M-44** (NGC-2632). Visible under a dark sky without optical aid, M-44 appears as a large, hazy patch of light containing a few bright stars. Because of its naked-eye visibility, M-44 was known in antiquity: Aratus called it the "little mist" as far back as 260 B.C., and Hipparchus referred to the cluster as a "little cloud" in 130 B.C. Aratus and Pliny used M-44 as a weather indicator: if the nebulous patch was invisible, the Greek astronomers forecast the imminent approach of a violent storm. More recently commentators have called M-44 "Praesepe," or the "Beehive," and this last name stuck, since many people agreed that when viewed with opera glasses the cluster's stars looked like a swarm of bees buzzing about their hive.

In 7x50 binoculars the Beehive's nebulous appearance vanishes and a myriad of stars becomes visible. The cluster contains fifty stars in an area measuring 95′ (nearly three Moon diameters) across. The brightest is Epsilon (ε) Cancri, a 6th-magnitude A-type star. Twelve more of its members — eight type-A stars and four K-type giants — shine brighter than magnitude 7.5. (As a standard of comparison, at M-44's distance of 160 parsecs the Sun would dimly glow at magnitude 10.9.)

For information on naked-eye sky viewing, including planets, constellations, and mythology, see **Eye on the Sky**.

These bright stars make M-44 a pretty area of sky to view with a small telescope. The cluster is so scattered you must use low-power eyepieces to see all of it at once. The most noticeable feature of M-44 in a 3-inch or 4-inch telescope is a trapezoid formed by magnitude 6.5 stars at the heart of the Beehive. Several arcminutes west is a bright triangle of stars, and some 20′ north lies a bright double star. Viewed with 10-inch or 12.5-inch telescopes, M-44 begins to lose its clustered appearance — these scopes have focal lengths long enough that even at low power their fields of view are rather restricted — and becomes a dull object. Perhaps the instrument best suited for viewing the Beehive cluster is a 4-inch rich-field telescope.

Eight degrees south and two degrees east of the Beehive lies Cancer's other open cluster, overshadowed by its famous neighbor to the north and completely ignored by many observers. **M-67** (NGC-2682) provides a marvelous contrast to the Beehive. Packing two hundred stars in a 30′ diameter, M-67 is a rich group of very faint stars, the brightest glowing at magnitude 9.7. The group's total magnitude is 6.9, which places it below the typical limit of naked-eye visibility.

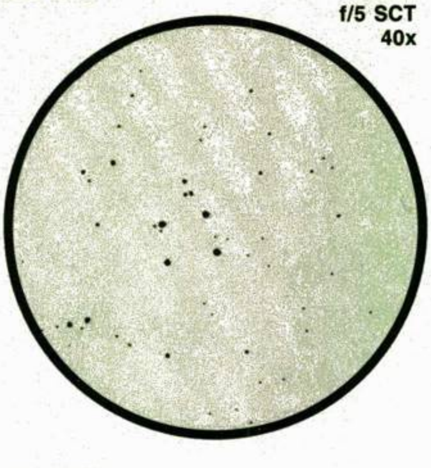
M-67 is a beautiful object. Two- and three-inch reflectors show a misty patch of light speckled with a few tiny, gleaming stars. A 6-inch telescope at 120x resolves the cluster into dozens of faint pinpoints, but an overall haze pervades the field of view. A 10-inch scope at 100x does a better job, because it resolves the group into what is clearly an open star cluster without nebulosity.

M-67 is one of the oldest open clusters known — estimated to be 3.2 billion years old. This explains why its many stars are so faint and yellow, orange, and red in hue: they are highly evolved old stars. Only NGC-6791 in Lyra and Melotte 66 in Puppis (6.3 billion years); NGC-188 in Cepheus (5 billion); NGC-2141 in Orion, NGC-2420 in Gemini, NGC-2506 in Monoceros, and NGC-7142 in Cepheus (4 billion); NGC-2243 in Canis Major (3.9 billion); and NGC-6819 in Cygnus (3.5 billion) are older. M-67 lies 800 parsecs away, five times more distant than the Beehive.

Cancer offers more than just two star clusters. Six degrees due north of the Beehive lies a tiny, faint galaxy called **NGC-2623**. This galaxy is hardly impressive unless it is viewed with a large backyard telescope: it dimly glows at magnitude 13.8 and measures a mere 30″ by 25″ across. However, NGC-2623 is an unusual target for two reasons: it lies a whopping 70 megaparsecs away and is a peculiar galaxy that — in long-exposure photographs — looks like two galaxies in collision. NGC-2623 has two long, thin streamers of material emanating from its core and it closely resembles the brighter

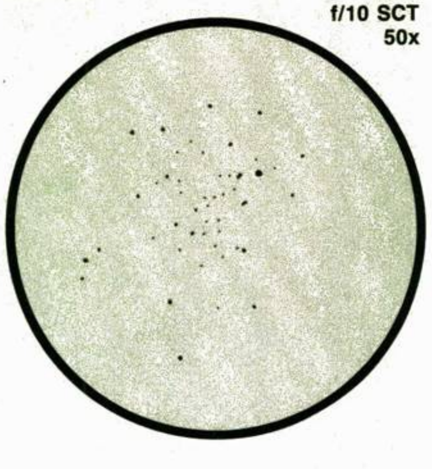
M-44

8-inch
f/5 SCT
40x



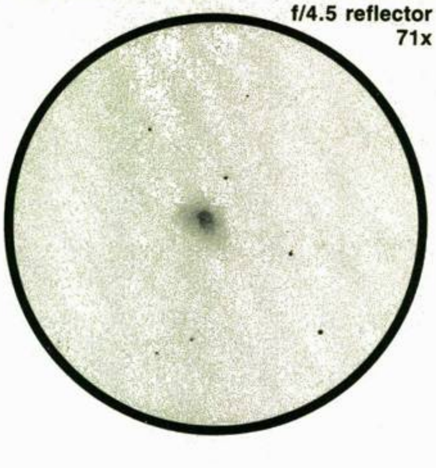
M-67

8-inch
f/10 SCT
50x



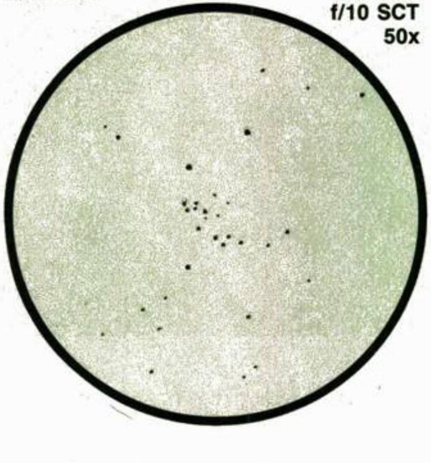
NGC-2775

17.5-inch
f/4.5 reflector
71x



M-48

8-inch
f/10 SCT
50x



Sketches by David J. Eicher

peculiar galaxy NGC-4038/9 in Corvus, the "Ring-Tail Galaxy."

The triple star **Zeta (ζ) Cancri**, 6° east and slightly south of the Beehive, provides a challenge to long-focal length instruments. Its three components shine at magnitudes 5.6, 6.0, and 6.2, and the corresponding separations are 0.8″ and 5.7″. Spotting the 6.2-magnitude star and the 5.6-6.0 pair is easy, but splitting the 5.6-6.0 pair is not unless seeing is steady and high power employed. All the stars are Sunlike in color.

Near the Cancer-Hydra border, 6° southeast of M-67, is another faint galaxy. **NGC-2775** is a 10th-magnitude spiral measuring 4.5′ by 3.5′ across; the galaxy appears as a nebulous streak of pale light in a 6-inch scope at 100x.

Hydra contains objects similar to those in Cancer, except its star clusters aren't as bright as those in Cancer. **M-48** (NGC-2548), on the extreme western side of Hydra, 4° southeast of Zeta Monocerotis, is a scaled-down version of M-44: it contains eighty stars in an area 54′ across, for a combined magnitude of 5.8. The stars aren't as bright as those in M-44, and the brightest only shines at magnitude 8.2. M-48 lacks the distinctive patterns seen in the Beehive but is nevertheless a fine field for scanning with a low-power eyepiece.

Hydra contains numerous galaxies, some of them bright when viewed with backyard telescopes. **NGC-2713** is a 12th-magnitude Sb-type spiral some 3.9′ long by 1.7′ across. It shows in an 8-inch scope as a moderately bright, oval fuzz surrounding a much brighter central glow. **NGC-2784** is a 10th-magnitude lenticular galaxy some 5.1′ by 2.3′ in extent: it appears as a football-shaped nebulosity with a bright, condensed nucleus. **NGC-2835**, a spiral measuring 6.3′ by 4.4′ and shining at magnitude 11.1 in blue light, is a fine galaxy for small telescopes because of its high surface brightness.

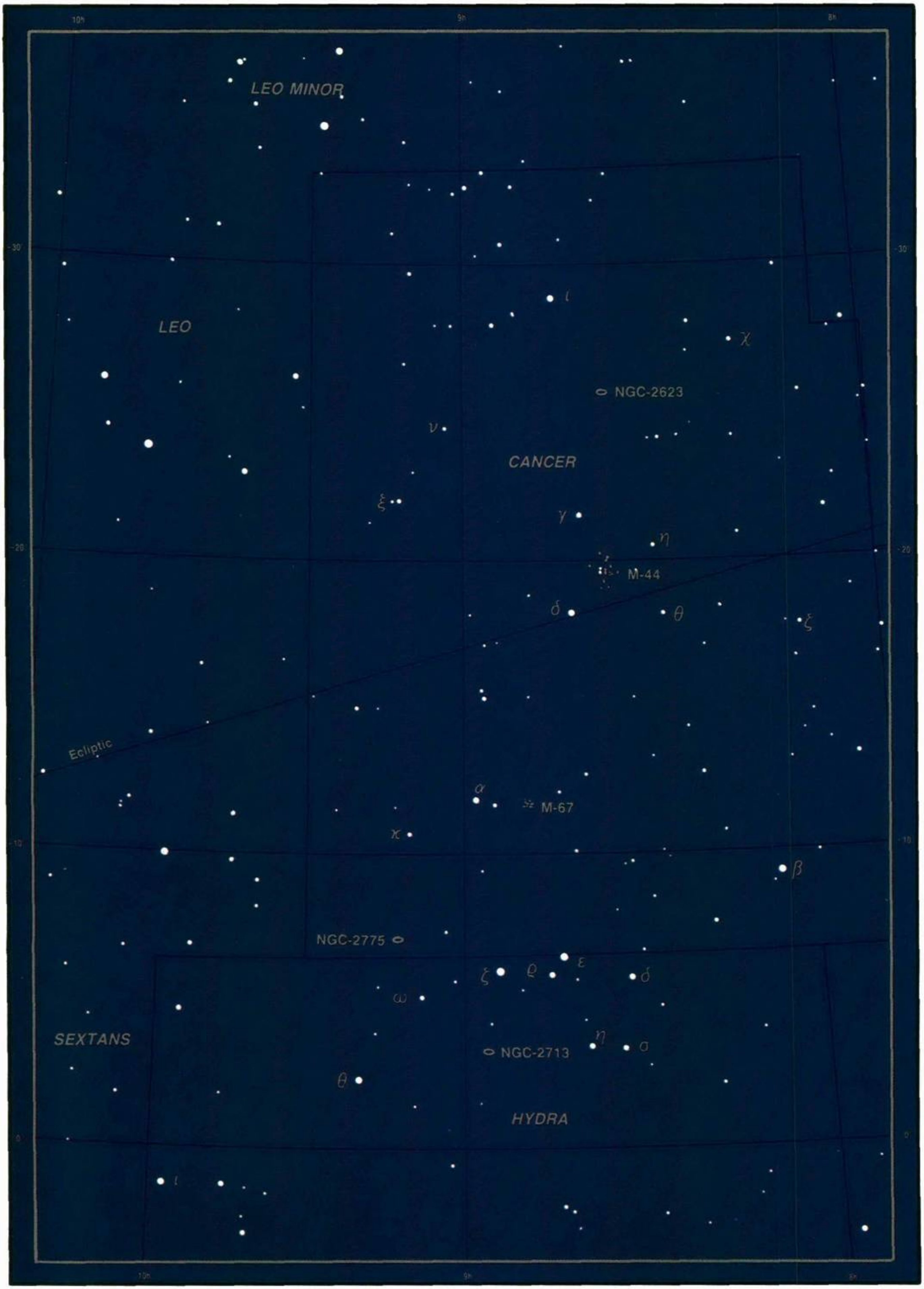
Farther east lie three more impressive galaxies. The 10.4-magnitude (blue light) irregular system **NGC-3109** shows as a patchy cigar-shaped blob in 8-inch scopes; **NGC-3124**, a fainter barred spiral, spans 3.2′ by 2.7′ and has a bright nucleus; and the spiral **NGC-3145** is visible in 6-inch scopes as a hazy smear of light surrounding an oval nucleus.

Object	M#	Type	R.A. (2000)	Dec.	Mag.	Size/Sep./Per.	H
Zeta (ζ) Cnc		★^{3}	8h 12.2m	+17°39′	5.6,6.0,6.2	0.8″,5.7″	
NGC-2548	M-48	⊙	8h 13.8m	−5°48′	5.8	54″	
NGC-2610		■	8h 33.4m	−16°09′	13.6_P	37″	
NGC-2623		#	8h 38.4m	+25°45′	13.8	0.6′x 0.5′	Pec
NGC-2632	M-44	⊙	8h 40.1m	+19°59′	3.1	95′	
Epsilon (ε) Hya		★^{4}	8h 46.8m	+6°25′	3.8,4.7,6.8	0.2″,2.8″	
					12.4	19.2″	
NGC-2682	M-67	⊙	8h 50.4m	+11°49′	6.9	30′	
NGC-2713		§	8h 57.3m	+2°55′	11.7	3.9′x 1.7′	Sb
NGC-2775		§	9h 10.3m	+7°02′	10.3	4.5′x 3.5′	Sa
NGC-2784		§L	9h 14.1m	−24°10′	10.1	5.1′x 2.3′	S0
NGC-2835		§	9h 17.9m	−22°21′	11.1_B	6.3′x 4.4′	S pec
NGC-3109		#	10h 03.1m	−26°09′	10.4_B	14.5′x 3.5′	Ir$^+$
NGC 3124		§B	10h 06.7m	−19°13′	12.4_B	3.2′x 2.7′	S(B)b$^+$
NGC-3145		§	10h 10.2m	−12°26′	12.4_B	3.3′x 1.7′	Sb$^+$

★^{3}	*Triple Star*
★^{4}	*Quadruple Star*
⊙	*Open Star Cluster*
■	*Planetary Nebula*
§	*Spiral Galaxy*
§B	*Barred Spiral Galaxy*
§L	*Lenticular Galaxy*
#	*Irregular/Peculiar Galaxy*

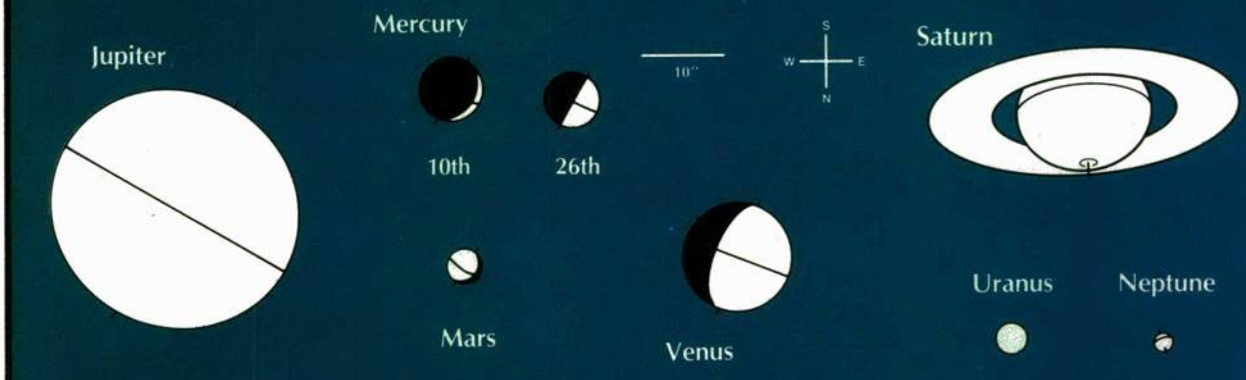
H = Hubble type for galaxies

Subscript "P" denotes photographic magnitude; subscript "B" denotes blue magnitude.

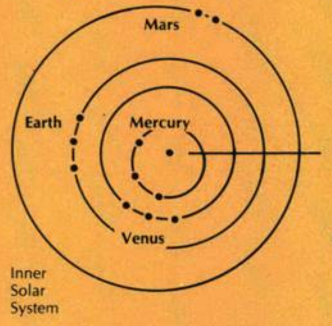

10h
9h
8h
LEO MINOR
30°
LEO
ι
χ
NGC-2623
ν
CANCER
ξ
γ
η
20°
M-44
δ
θ
ζ
Ecliptic
α
M-67
κ
10°
β
NGC-2775
ζ
ρ
ε
δ
ω
SEXTANS
η
NGC-2713
σ
θ
HYDRA
0°
ι
10h
9h
8h

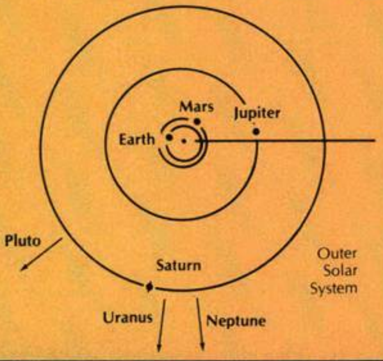
Planetary Data

March 1987


Jupiter
Mercury
10th
26th
10″
S
W
E
N
Saturn
Mars
Venus
Uranus
Neptune

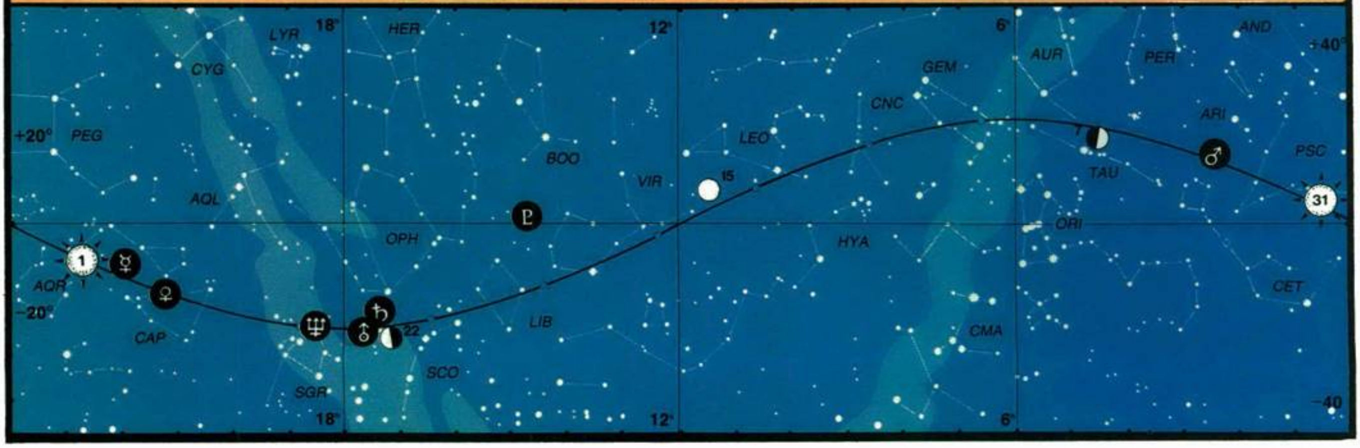
		Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Sun	Longitude: Heliocentric	Ecliptic	R.A. (2000.0)	Dec.
Sun		1	−26.8	32.3′	—	0.991	—	—	339°52.2′	22h 46.3m	−7°48.3′
		15	−26.8	32.2′	—	0.994	—	—	353°52.6′	23h 38.2m	−2°21.8′
		31	−26.7	32.1′	—	0.999	—	—	9°45.3′	0h 36.5m	3°56.0′
Mercury	☿	1	4.5	10.7″	1%	0.629	0.367	164°23.8′	337°25.2′	22h 31.0m	−5°23.1′
		15	0.9	9.2″	30%	0.731	0.438	215°58.1′	330°33.1′	22h 08.4m	−10°01.7′
		31	0.2	7.0″	58%	0.961	0.466	261°28.9′	342°33.0′	22h 58.5m	−8°35.0′
Venus	♀	1	−4.2	16.7″	69%	1.002	0.724	229°24.9′	297°29.0′	19h 57.2m	−19°34.5′
		15	−4.1	15.2″	73%	1.101	0.726	251°42.9′	313°55.3′	21h 05.3m	−16°28.5′
		31	−4.0	13.8″	78%	1.208	0.727	272°04.6′	332°57.9′	22h 20.7m	−11°05.5′
Mars	♂	10	1.3	4.9″	93%	1.903	1.529	73°13.2′	42°07.2′	2h 37.9m	16°02.7′
		20	1.4	4.7″	93%	1.982	1.542	78°21.4′	48°55.5′	3h 05.1m	18°07.2′
Jupiter	♃	15	−2.0	33.2″	100%	5.936	4.957	4°44.3′	3°06.5′	0h 13.1m	0°14.2′
Saturn	♄	15	0.5	16.7″	100%	9.905	10.022	255°15.5′	261°07.1′	17h 21.8m	−21°35.6′
Uranus	⛢	15	5.6	3.7″	100%	19.218	19.197	263°38.1′	266°38.8′	17h 45.9m	−23°32.0′
Neptune	♆	15	8.0	2.2″	100%	30.461	30.237	275°59.3′	277°55.0′	18h 34.6m	−22°10.8′
Pluto	♇	15	13.7	0.1″	100%	29.021	29.694	218°15.6′	219°39.4′	14h 50.7m	1°08.2′


Mars
Earth
Mercury
Venus
Inner Solar System


Mars
Jupiter
Earth
Pluto
Saturn
Outer Solar System
Uranus
Neptune

Moon Data

First Quarter..........March 7 at 11h58m
Full Moon...........March 15 at 13h13m
Last Quarter.........March 22 at 16h22m
New Moon..........March 29 at 12h46m
First Quarter............April 6 at 7h48m
Full Moon.............April 14 at 2h31m
Apogee: Mar. 9 at 10h30m....404,778 km
Perigee: Mar. 24 at 19h04m....368,977 km


LYR
18°
HER
12°
6°
AUR
AND
PER
+40°
CYG
GEM
CNC
ARI
+20°
PEG
LEO
7
BOO
VIR
15
TAU
PSC
AQL
31
ORI
OPH
HYA
1
AQR
CET
−20°
22
LIB
CAP
CMA
SCO
SGR
18°
12°
6°
−40

Mercury

Mercury reaches greatest western elongation from the Sun in the morning sky on March 26. But, despite a large angular separation (28°), the planet's elevation never climbs higher than 3° (as seen 45 minutes before sunrise). This is because the ecliptic makes a shallow angle to the horizon at this time of year in the Northern Hemisphere, which prevents Mercury's otherwise ample separation from the Sun from translating into a high elevation and easy visibility.

Best viewing is around the dates of highest elevation (March 19 to 21) with the observing technique identical to that for Venus: locate the planet while it is low and continue following it as twilight grows brighter until Mercury's disk is too washed out to see.

Venus

Venus is still brilliant, but it is sinking swiftly in the eastern sky as the month progresses. As with Mercury the best telescopic observing method is locating Venus in a fairly dark sky (while it is low) and then keeping your scope trained on the planet as it rises. Up to a point, the brightening dawn sky actually makes viewing easier because it cuts the glaring contrast between the white, cloud-decked planet and the dark sky around it.

Earth

The center of the Sun crosses the celestial equator in a northward direction at 3h52m UT on March 21. This is the vernal equinox, which marks the start of spring in the Northern Hemisphere.

Moon

An annular-total eclipse of the Sun occurs at New Moon (March 29), but the event is visible only from South America, Africa, Arabia, southeastern Europe, and southwestern Asia.

Mars

Although Mars is a prominent object in Aries below the Pleiades star cluster, the Red Planet won't reveal very much when you train your telescope on it. On March 6, Mars' disk is 5″ across and may reveal a slightly gibbous shape all month long if the seeing is steady enough. The gibbous shape happens because Mars is now near quadrature, a time when the planet and the Sun are 90° apart in our sky. At eastern or western quadrature we can peek a little beyond the Martian terminator onto the planet's nightside hemisphere. In this case, the predawn side of Mars and the sideview make the disk appear slightly out-of-round. (See the drawing in the Planetary Data section, page 106.)

The Cocoon Nebula in Cygnus, like a more distant version of the Orion Nebula, is a region of ionized hydrogen gas excited by an embedded star. Bill Iburg made this photo using a 14-inch f/7 SCT, hypered Konica SR400 film, and a 40-minute exposure.

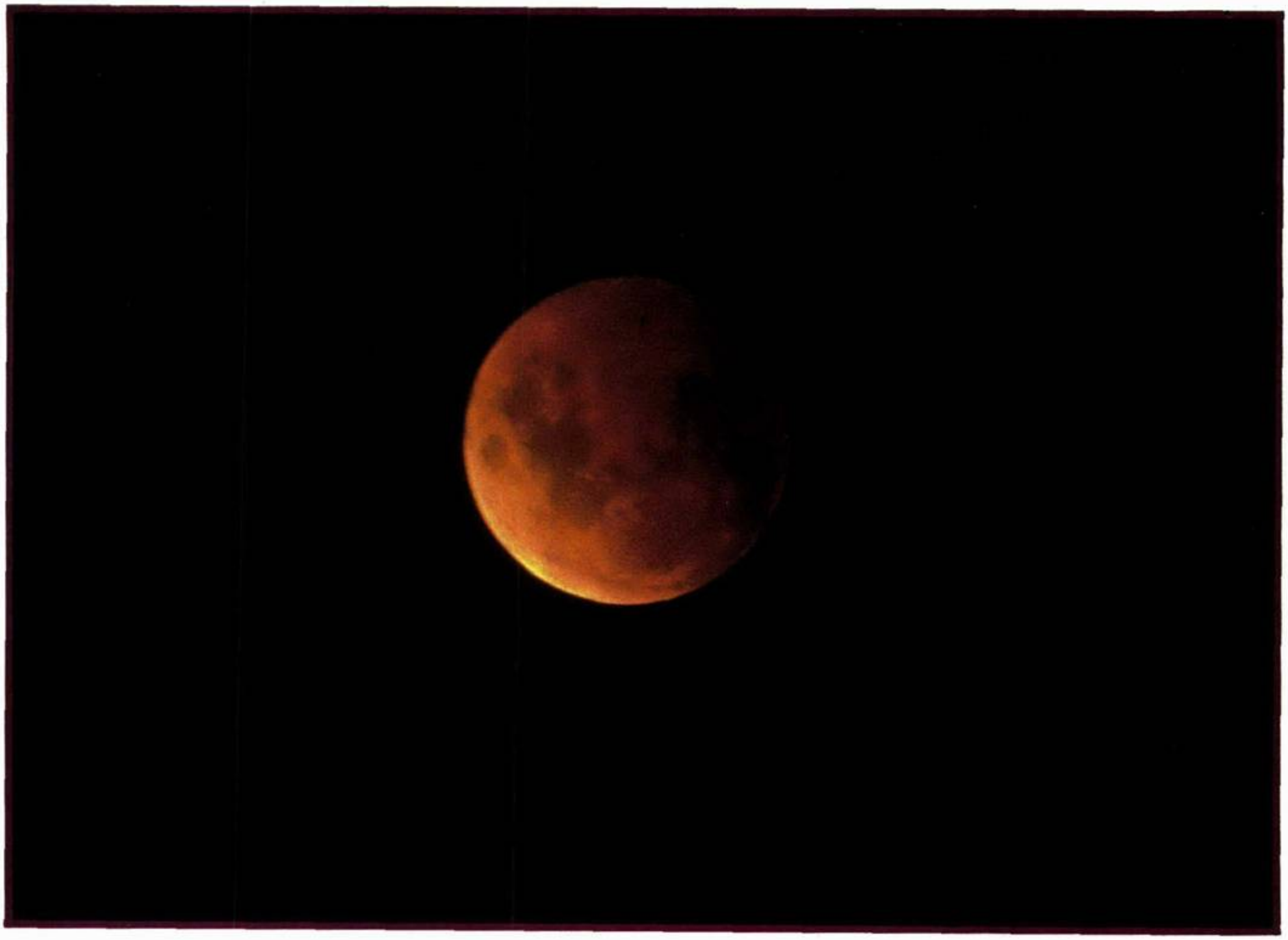
Minor Planets

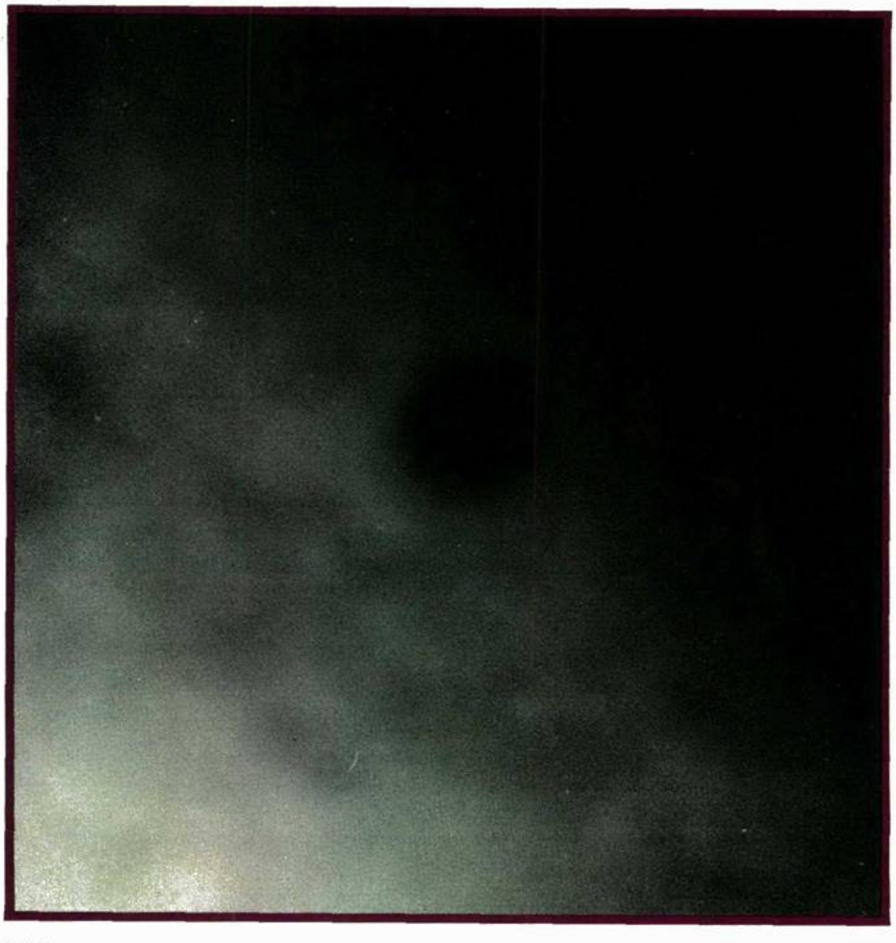
1 Ceres (magnitude 8.1) is moving eastward in Sagittarius north of the Lagoon and Trifid nebulae. Its positions:

1st: 17h 43m 43s, −20° 45.8′
10th: 17h 54m 09s, −21° 02.5′
20th: 18h 04m 21s, −21° 19.6′
30th: 18h 12m 51s, −21° 36.6′

Ceres rises about 2:30 a.m. local time on the 15th.

2 Pallas (8.9) lies in southern Ophiuchus





Above: A last sliver of light enhances the eastern limb of the copper-colored Moon just before totality during the October 17, 1986, total lunar eclipse. Photo by Jean Dragesco, who used a 600mm lens, Ektachrome 100 film, and a 60-second exposure.

Left: George D. Georgiadis made this photo of Mercury's transit of the Sun on November 13, 1986, without the aid of a solar filter. The photo also shows granules — convective cells in the Sun's photosphere. Georgiadis used a 14-inch SCT at f/11, a violet filter, Kodalith 8 film, and 1/2,000-second exposure.

near the border with Scorpius. Its positions:

1st:	16h 14m 15s,	8° 33.7′
10th:	16h 20m 01s,	10° 40.6′
20th:	16h 24m 12s,	13° 12.0′
30th:	16h 25m 52s,	15° 49.5′

Pallas rises around 11:30 p.m. local time at mid-month.

3 Juno (10.9) is moving northeastward from Capricornus into Aquarius. Its positions:

1st:	20h 18m 17s,	−10° 35.7′
10th:	20h 31m 20s,	−9° 47.8′
20th:	20h 45m 25s,	−8° 50.5′
30th:	20h 58m 59s,	−7° 49.9′

Juno rises around 4:30 a.m. local time on the 15th.

4 Vesta (8.5) lies in the tail of Cetus. Its positions:

Gary Capps' stunning photo of the elusive Horsehead Nebula is this months's $100 "Best Astrophoto" winner. Capps made this 75-minute exposure using a 12-inch Astromak and Spectroscopic 103a-F film.

1st: 1h 55m 03s, 6° 27.1′
10th: 2h 08m 21s, 7° 55.7′
20th: 2h 23m 40s, 9° 31.7′
30th: 2h 39m 29s, 11° 04.1′

Vesta sets around 9 p.m. local time on the 15th.

354 Eleonora (10.4) is moving retrograde in Coma Berenices. Its positions:

1st: 12h 21m 05s, 14° 39.9′
10th: 12h 16m 04s, 16° 37.2′
20th: 12h 09m 22s, 18° 36.2′
30th: 12h 02m 21s, 20° 12.8′

At opposition on March 22, Eleonora is visible all night long.

To locate a minor planet, plot its dated positions (given for 0h UT) lightly in pencil on a good star map (*Sky Atlas 2000.0*, for example) and sketch a smooth curve linking the points. Then observe the starfield at low magnification and photograph or plot by hand what you see. Check the field a night or two later; the "star" that moved is it. (All minor planet coordinates are for the epoch 2000.0.)

Jupiter

Jupiter vanishes from sight in the evening sky by the end of the first week of March. It reaches conjunction with the Sun on March 27 and will reappear low in the morning sky by mid-April.

Saturn

By sunrise Saturn crosses the meridian in the south and reaches its highest elevation (25° to 35°, depending on your latitude). The rings, tipped 26.5° to our view, form a splendid sight. In 1656 when Dutch astronomer Christaan Huygens thought he had finally discovered what the rings looked like (many early telescopes lacked good definition), he announced his findings in a Latin anagram. Deciphered and translated, the anagram read: "It [Saturn] is circled by a thin ring, flat, attached nowhere, and inclined to the ecliptic," which also precisely describes what your scope, using moderate power, will show.

Saturn's pale ivory color becomes more noticeable as dawn lights up the sky around it. Also look carefully to see if its bright belts and darker zones become easier to spot as the sky brightens.

Uranus

In March Uranus is in the predawn sky among the stars of western Sagittarius. It lies about as far east as it will be until conjunction this December. Uranus is halfway between the Lagoon and Trifid nebulae (M-8 and M-20) and about 17 minutes of right ascension (4.5°) west. Use low power and sweep the correct area. When you spot a bright blue-green "star," use a higher-power eyepiece to confirm the planet's 3.7″ disk.

Neptune

Also in Sagittarius, Neptune lies 30 minutes of right ascension east and about half a degree north of the Trifid Nebula, or about 4° northeast of Lamda (λ) Sagittarii. Look for a blue-gray disk 2.2″ across.

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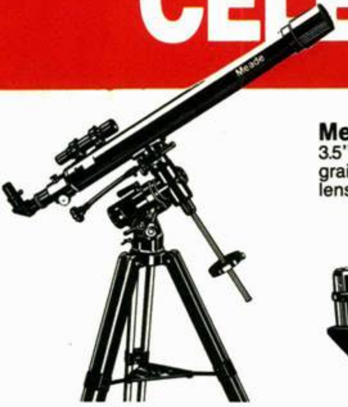

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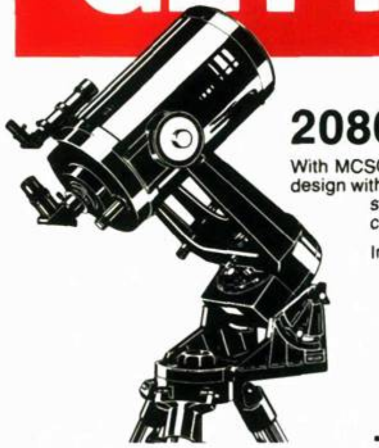

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